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V. p. 478

BIOLOGICAL INVESTIGATION OF
SPHENOPHORUS CALLOSUS OLIV.

Z. P. METCALF

BULLETINS OF THE STATION WILL BE SENT FREE TO CITIZENS OF THE STATE ON REQUEST

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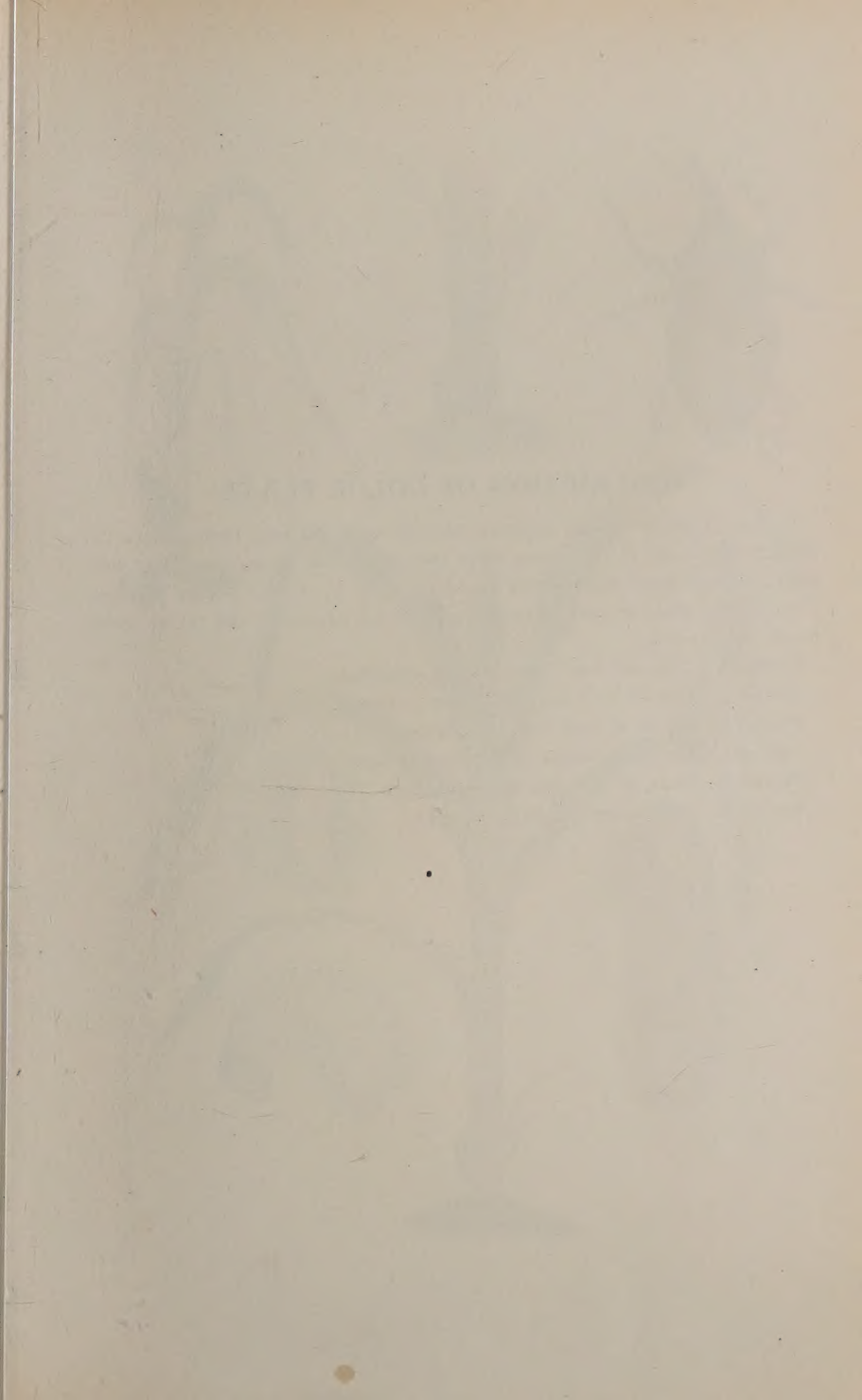
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DESCRIPTION OF COLOR PLATE

FIGURE 1. Stalk of corn showing how the corn bill bug, feeding near the ground, eats holes in the leaves when they are rolled up, so that when they unroll rows of holes show across the leaf. Adult in normal feeding position.

FIGURE 2. Stalk of corn showing the stunting caused by the larvae working in the tap-root.

FIGURE 3. Corn bill bug laying egg in cornstalk.

FIGURE 4. Egg of corn bill bug, much enlarged.

FIGURE 5. Larva of corn bill bug, enlarged.

FIGURE 6. Larva in tunnel in tap-root of corn.

FIGURE 7. Pupa of corn bill bug, enlarged.

FIGURE 8. Adult corn bill bug, enlarged.



PREFACE

The corn bill bug has long been recognized as one of the important insect enemies of corn in this State. Farmers generally are fairly well acquainted with its ravages, although, needless to say, it is not unusual to find the work of this insect confused with the work of other insects which injure the same parts of the plant.

Recognizing the importance of this pest and appreciating the lack of definite knowledge of this insect, Mr. R. I. Smith, then Entomologist of this Station, began an investigation of the corn bill bug in June, 1910, under an Adams Fund Project, entitled "A Biologic Study of the Species of the Genus *Sphenophorus* in North Carolina." Mr. Smith continued the investigation of this insect until he severed his connection with the Station in the fall of 1911. A report of Mr. Smith's investigations may be found in the Thirty-fifth Annual Report of the North Carolina Agricultural Experiment Station for the year ending June 30, 1912, pages 105 to 135.

The writer took up active work on the corn bill bug project when he was appointed Entomologist in the spring of 1912, and continued working actively on this project until the fall of 1915. Needless to say, the writer has drawn extensively upon Mr. Smith's paper in writing this bulletin, as Mr. Smith's work and the writer's have formed separate parts of one project. Mr. Smith's work was done largely in the laboratory and insectary. The writer's has been about equally divided between the laboratory and the field. Our results do not always coincide perfectly, due, perhaps, as much to methods and angle of approach as to any factor. Certainly, where conflicting reports are found it will be discovered on inspection that they are well within the probable error for such results.

This investigation has covered in all about five years, and while there are some phases of the question that are still undecided, it is thought that the investigation has reached such a stage that a report upon the biologic and economic aspects of the investigation is entirely justified, leaving a discussion of the other phases of the problem until another time.

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BIOLOGICAL INVESTIGATION OF SPHENOPHORUS CALLOSUS OLIV.

BY Z. P. METCALF

HISTORY, SYNONYMY, AND CLASSIFICATION

The corn bill bug (*Sphenophorus callosus* Olivier) belongs to the family *Curculionidæ*, the sub-family *Calandrinæ* of the sub-order *Rhynchophora*. This family includes various species of bill bugs proper, many of which are of economic importance in the United States, preying upon corn, grasses, etc., and the rice and granary weevils which feed upon various kinds of stored products and grains.

Blatchley and Leng (1916) describe the sub-family *Calandrinæ* as follows: "A rather small group of usually large, robust species, having the antennæ elbowed, inserted near the base of beak, their grooves very short, not receiving the scape; funicle 6-jointed, club not annulated, shining; labrum wanting; mouth cavity elongate, peduncle of mentum narrow, elongate, concealing the oral organs; mandibles compressed, with three apical teeth; beak variable in length and sculpture; thorax truncate in front and beneath, without ocular lobes; elytra without epipleuræ and with a strong fold on inner face; abdomen with five ventral segments, the first and second longer, the third and fourth short, their sutures straight and deeply impressed, fifth equal to third and fourth fitting into the groove of the underside of elytra; last spiracle covered by the ventral segments; pygidium large, nearly perpendicular, exposed in both sexes; last dorsal of male quadrate and more or less retracted or concealed; coxæ all more or less separated, the hind ones transverse, oval; femora usually strongly clavate, not toothed; tibiæ short, not serrate, clawed at the outer angle; tarsi rarely brush-like beneath, third joint rarely bilobed; claws divergent, simple.

"The larvæ of the larger species bore into the stems of plants, especially grass and corn, while those of the smaller ones infest seeds and grain."

The genus *Sphenophorus* Schoenherr is world-wide in distribution, containing species that are of economic importance in several countries. It was described in 1837 by Schoenherr as follows:

Genus 390. Sphenophorus nobis.

Rhynchophorus Herbst. Schh. (1) Say—*Calendra* Clairville, Illiger, Germar; (2) *Calandra* Fabr. Olivier, Latreille, Germar, Dejean, Illiger, Oken, Sturm; (3) *Curculio* Linne et plures.

CHARACTER GENERIS—Antennæ mediocres validiusculæ articulis duobus basalibus funiculi oblongis turbinato-obconicis, reliquis brevibus, sub-rotundatis omnibus distanibus clava breviter ovata, compressa, cuneiformis.

Rostrum elongatum, sub tenue, basi crassius, modice arcuatum, Thorax oblongus, antic angustior valde coarctatus, basi aut bi-sinuatus, aut rotundatus.

Elytra oblonga, sub ovata, apice in pleurisique singulatim rotundata, supra saepissime planiuscula.

Pedes mediocres, validi, longitudine sub aequales.

DESCRIPTION—Corpus elliptico-ovolum, supra aut planiusculum, aut paravum convexum, alatum, plerumque mediae magnitudinis. Antennae thoracis medium pertingentes, prope basim rostri insertae, validusculae, fractae, articulatae, scapo elongato thoracem apice attingente, sub-clavato; funiculo 6-articulato; articulis, 1, 2 oblongis, turbinato, obemicis, 3-6 in plerisque sub-rotundatis in caeteris sub-turbinatis, exterioribus successive parum crassioribus, omnibus distantibus; clava breviter ovata, compressa, cuneiformis bi-articulata; articulo 1° corneo, apice truncato, 2° spongioso, apice acetoto, aut truncato, aut sub-rotundato. Rostrum fere longitudine throacis, ante insertionem antennarum crassius dein sub-tenne, arcuatum, deflexum. Ocli laterales, infra caput fere connexi, oblongi depressi. Thorax latitudine baseos longior in plerisque bisinuatus, in allis rotundato productus, lateribus in plerumque basi sub-rectis, dein versus apicem porum rotundatis; anterieus angustior, in nonnullis magnis aequaliter rotundatus, antice subito angustior, semper longe intra apicem profunde, coaratus collum quasi annuliforme formans convexus. Scutellum triangulare. Elytra antice thoracis basi parum latiora et illa fere sesqui-longiora basi partim singulatim, sub-rotundata, partim conjunctum introsum rotundata—emarginata pone basim oblique ampliata dein posterius attenuata apice obtusus rotundata, aut sub-truncata, abdomine breviora, supra in plerisque planiuscula in paucis nonnihil convexa. Pygidium sub-triangulare, deflexum. Pedes mediocres, longitudine sub-aequales validi; femoribus clavatis, saepissime muticus raro sub-tusfixo, valido terminatis tarsi, elongatis, articula penultima, aut majusculo, subtus spongioso, out paulo minori subtus haud spongioso, unguiculari elongato clavato bi-inguiculata.

Typhus Sphenophorus abbreviatus.

(Patria Totus orbis; praesertim vero regiones calidae.)

OBSERV.—In numeroso hoc genere occurrunt quaedam species nonnullae, omnibus supra indicatis characteribus non exacte convenientes; dum vero notis generis maxime essentialibus correspondent, illas separare minus necesse censui. Inveniuntur elim aliae quarum forma corporis paulo convexior et tarsi diversimoda constructi pro quibus, ut interim saltem stirpem peculiarem assignavi.

Riley (1881) gives the following as the distinguishing characters of the genus:

"The distinguishing generic characters of *Sphenophorus* may be given briefly as follows: Side pieces of metasternum rather narrow; epimera of mesosternum externally truncate (not acute); front coxae narrowly separated by the prosternum; third joint of the hind tarsi either glabrous or only pubescent on the sides. A peculiar external appearance will render the genus at once recognizable to the experienced eye, while the numerous species are very difficult to distinguish. The form of the tibia and tarsi and the vestiture of the latter have furnished excellent characters to divide the genus into natural groups. That to which our species (*robustus*) belongs is characterized as follows:"

Blatchley and Leng (1916) describe the genus *Sphenophorus* as follows: "Rather large, robust, usually elliptic-ovate species, having the

body glabrous, often covered with a clayey artificial coat so as to hide the sculpture, more rarely with a dense natural glabrous coating; antennæ inserted near base of beak, scape long, slender, funicle six-jointed; club wedge-shaped, convex in front, the outer third of more sensitive; beak shorter than thorax, rather slender, feebly curved, swollen at base; antennal grooves very short, fovea-like, located close to eyes; thorax longer than wide, its disc usually with elevated smooth lines or spaces; elytra usually wider than thorax, their tips separately broadly rounded, thus widely exposing the pygidium."

The species that we are interested in was described by Olivier in 1807 as *Calandra callosa* from "Carolina," a region of great extent and including the greater part of the range of this species as we know it today. Olivier's description is as follows:

27 *Calandra calleuse*, *Calandra callosa*, Charausion, pl. 28 Fig. 416. C. d'un noirgris obscur; elytres avec un point calleux luisant. C. obscura cincerascens, elytris puncto culloso nitido.

Antennæ nigræ apice cinero. Rostrum nigrum basi fusco-cinereum. Thorax fusco-cinereus obscurus dorso cruce vix elevata. Elytra haud striata subvariolora fusco-cinerae obscura callo postico nitido. Corpus subtus pedesque fusco-cinerae obscura.

Tout le corps de cet insecte est d'un noir de cendre obscur. Les antennes sont d'un noir brun, luisant, avec la base cendrée, obscure. Le corcelet est inégal et on voit à sa partie supérieure une élévation en croix peu marquée les élytres sont inégales, presque varioleées, marquées, vers l'extrémité d'un point calleux presque épineux, noirâtre, luisant.

Elle se trouve dans la Caroline.

Du cabinet de M. Bosc.

In 1837 Schoenherr redescribes this species in his "Genera et Species curulionidum" as follows:

71 *S. CALLOSUS* OLIVIER.

Ellipticus, niger, opacus, indumento fusco-cinereo, undique incrustatus; thorace, inaequali, varioloso-punctato plagis tribus elevationibus, natato media sub-cruciformi, elytris obsolete, remote punctato striatis, callo postico elevato nitido.

Calandra Callosa Oliv. Ent. V. 83, pp. 92, 27.

Patria America Septentrionalis.

This species seems not to have been referred to again until 1873, when Le Conte and Horn in their *Rhynchophora of America North of Mexico* unite this species with *S. cariosus* Oliv., stating their reasons for so doing as follows:

"Dr. Horn has suggested to me that this species and *S. callosus* Oliv. should be united. After careful examination of the specimens in my collection, I think this view is correct. Those who are inclined to adopt it will place *Callosus* as the synonym, since it is represented by old and abraded specimens."

S. callosus Oliv. was therefore considered a synonym of *S. cariosus* Oliv. until 1906, when Chittenden (1906) cleared up the situation by pointing out that *callosus* must be considered as distinct from *cariosus*. That portion of his paper which refers to *callosus* is as follows:

SPHENOPHORUS CALLOSUS OLIVIER.

Calandra callosa Oliver, Hist. Nat. des Ins., Vol. V., p. 92, Pl. XXVIII. Fig. 416, (1807).

Sphenophorus sculptilis Horn (nec Uhler). Proc. Am. Phil. Soc., p. 424 (1873).

This species was united by Le Conte and Horn with *cariosus*, but wrongly so, as I shall attempt to prove. Olivier's description reads in substance as follows:

"Body black with dark cinereous coating. Antennæ brownish black, shining, cinereous at apex. Rostrum black, *dark cinereous at base*. Thorax uneven, and one sees on the superior portion an elevation in the form of a cross, feebly marked." Elytra uneven, feebly variolate, marked toward the apex with a callous point, nearly spinose, blackish, shining.

"Olivier's illustration is imperfect in that it is very crude, showing neither punctuation nor sculpture, and the general impression is that of a shining species, which was certainly not intended. The thorax is a little short, otherwise the form coincides with the species which is figured herewith.

"The cinereous base of the rostrum is an important character, as it signifies that a considerable portion of the base is coated, while in *cariosus* it is not. The cross-like elevation of the thoracic disk is aptly described as *feebly* indicated; in fact, it requires little imagination to discern it in many individuals; moreover, it is not shown in Olivier's figure. In the true *cariosus* the cross is black, shining, and well marked, and the cariniform base of the third elytral interval which is always present is so prominent as to attract the attention of the veriest tyro.

"The type locality 'Carolina' will answer for either species. North Carolina appears to be the metropolis of *callosus*."

Blatchley and Leng (1916) described *Sphenophorus callosus* Oliv., as follows:

"Oval robust. Black, densely clothed with a brownish or olivaceous clayey coating; antennæ and tarsi reddish-brown. Beak two-thirds the length of thorax, compressed and sparsely punctate except near base, where it is swollen, coarsely punctate, and shallowly grooved above. Thorax slightly longer than wide, sides parallel from base for three-fourths their length, then strongly rounded to the constricted apex; disc very coarsely and irregularly punctate, the median vitta usually broadly dilated at middle, its apical portion very narrow; lateral vittæ broad at base and with a short oblique branch, their front portion often replaced by coarse punctures. Elytral oval, their surface uneven, sides gradually narrowed from humeri to apex; striæ fine, coarsely and distinctly punctate; intervals flat, their punctures hidden, the third sometimes feebly base. Humeral umbone and sub-apical callus somewhat prominent, often shining. Under surface coarsely and sparsely punctate. Length, 8-12 mm."

The synonym of this species would therefore seem to be as follows:

1807. *Calandra callosa* Olivier. Hist. Nat. des Ins. Vol. 5, p. 92, pl. 27, fig. 416.

1837. *Sphenophorus callosus* Olivier. Schoenherr Genera et species curculionidum, page 492.

1873. *Sphenophorus sculptilis* Horn (nec Uhler). Rhynchophora of America North of Mexico, page 424.

1873. *Sphenophorus cariosus* Le Conte and Horn. Rhynchophora of America North of Mexico, page 425.

1906. *Sphenophorus callosus* Chittenden. Proc. Ent. Soc., Wash. Vol. 7, pp. 166-182.

DISTRIBUTION

The distribution of the corn bill bug as recorded by Blatchley and Leng (1916) is as follows: Maine to Florida, westward to Arizona and northern Mexico and northward to Wisconsin (Fig. 1).

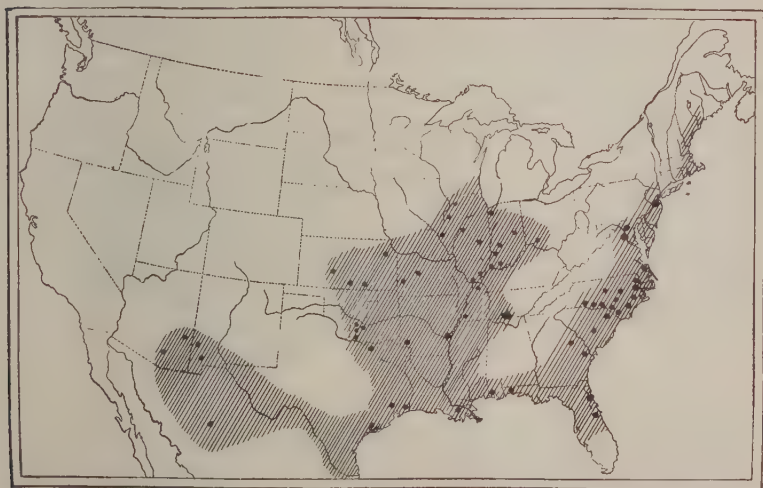


FIGURE 1. Map of the United States showing the distribution of the Southern Corn Bill Bug. Dots show recorded distribution. Shaded area approximate distribution. (In part after Webster.)

In this State it is largely confined to the region known as the Coastal Plain. This in a general way corresponds to the Lower Austrial Life Zone. Its distribution in the State as determined by the records of the United States Bureau of Entomology and the records in this office are shown graphically in Fig. 2. The dots show places where this insect has been found by field investigations or by correspondence. The shading indicates the approximate distribution of this species in the State.

In the map (Fig. 2) the area of especial destructiveness to corn is shown by double shading.

In the writer's experience, this insect is almost universally present in the eastern part of its range. In the western part of its range, however, it is confined to the low swampy situations along streams. This would indicate very strongly that the insect is very dependent upon soil with a great amount of water for its best development.

In the western part of its range it may be as abundant on cyperus as in similar situations in the eastern part of its range, and although corn is frequently planted in close proximity to such low swamps, the corn bill bug does not, so far as our observations go, turn its attentions from the cyperus to the corn.

DESTRUCTIVENESS

Probably no corn insect causes as great loss both directly and indirectly in the eastern part of this State as the corn bill bug. Complete destruction of entire fields is not only frequent, but common. Farmers frequently replant such fields in the hope of getting a stand, but it is not at all unusual for the third and often for the fourth planting to be so badly injured as to cause the farmer to abandon the field entirely.



FIGURE 2. Map of North Carolina showing the distribution of the Southern Corn Bill Bug. Dots show actual records. Shaded portion approximate distribution. Doubly shaded portion area of greatest destruction.

As swamps are drained and put under cultivation the usual practice is to farm to corn for the first few years. The corn bill bug, driven from its natural food plant, turns its attention to the corn, and does so much damage that the growing of corn under such conditions is rendered entirely without profit.

A general conception of the appearance of such fields may be gathered from an examination of Figs. 3 and 4. In really serious cases of damage from this insect practically every stalk will be destroyed or only a stalk here and there will escape destruction. In cases of milder amount of damage more stalks will escape destruction, but a great many stalks will be so badly deformed that they make no satisfactory growth

and never produce ears. A few stalks more favorably located will make a fair growth and will stand above their neighbors like giants among dwarfs.

The very irregular growth of the stalks in the field is perhaps the best indication of the presence of the corn bill bug. Other indications are the rows of very regular holes across the leaves, and the presence of the adults clinging to the base of the stalk and the presence of the larvæ in the stalks and among the roots.

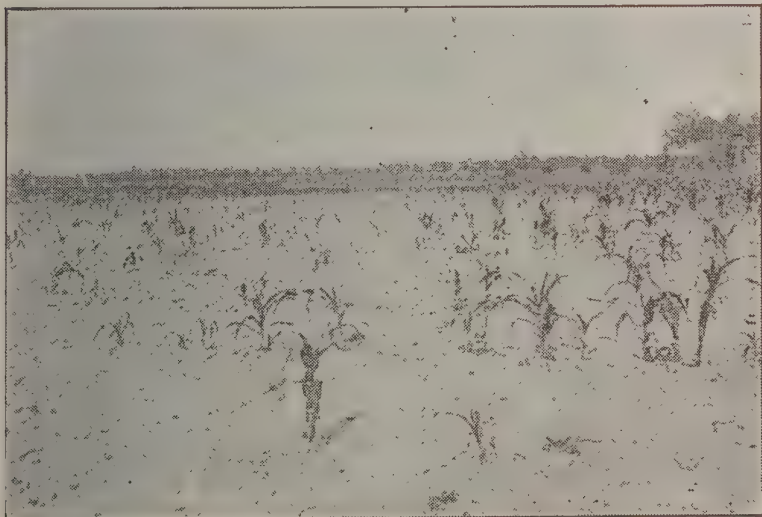


FIGURE 3. Field of corn, showing characteristic injury by Southern Corn Bill Bug.

In fields examined in this State the writer has tried as far as possible to determine the relative amount of damage that has been caused by corn bill bugs under different conditions, and while no entirely satisfactory method has ever been devised for expressing the amount of damage caused under different conditions in different fields, he has as far as possible tried to express this in a rate per cent, basing his conclusions upon a careful stalk-to-stalk examination of representative areas and also by a summary of the field as a whole after a careful survey.

Needless to say, a stalk-to-stalk inspection alone will not be an entirely satisfactory basis for estimating damage, for very frequently stalks are damaged so slightly by the adult beetles that the stalk will afterwards almost completely recover. This is especially true where the total number of beetles is small and the percentage of stalks damaged is relatively small.

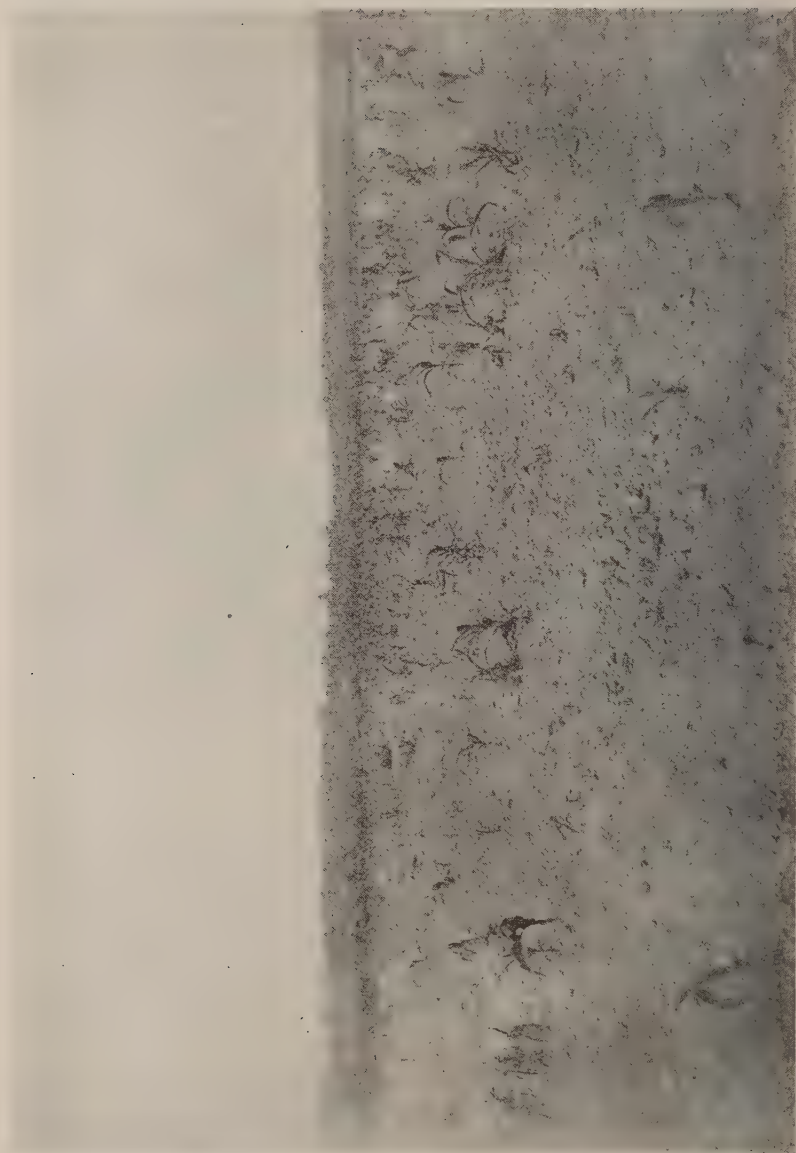


FIGURE 4. Field of corn, showing injury by Southern Corn Bill Bug.

COMMON NAMES

The southern corn bill bug has a large number of names in this State, the most common being derivatives of the name "Curlew Bug." The name "Curlew Bug" is given on account of its fancied resemblance to the Curlew. The curlew was a fairly common bird on our coast with a long curved bill resembling to a certain extent the snout of the corn bill bug. Some of the more common corruptions of the name "Curlew Bug" are "Klew" or "Clew Bug" and "Curlic Bug." It is also generally known as "bill bug" and "corn bill bug." The rice growers speak of it familiarly as "Rice Bug" and "Rice Bill Bug." In other sections it is known almost exclusively as "Chufa Bug" from its habit of feeding to a great extent upon the chufa. Other names may be used in various localities, but in the writer's experience these names are the ones most commonly used.

In this report the writer has adopted the name Southern Corn Bill Bug to distinguish it from other corn bill bugs found in other parts of the country. The writer feels that the selection of this name needs no special defense. He has selected it in place of the more common "Curlew Bug" for the reason that it calls to one's attention at once that this is the bill bug that is especially destructive to corn in the Southern States which the name curlew bug does not suggest.

INSECTS WHICH ARE OFTEN MISTAKEN FOR THE SOUTHERN CORN BILL BUG

There are in this State many different kinds of snout beetles, any one of which is apt to be mistaken by the farmer for the Southern Corn Bill Bug; but so far as the writer is aware, none of these snout beetles save the corn bill bug has the habit of feeding at the base of corn-stalks, head downward. (Fig. 5.)

The work of various kinds of insects is often mistaken for the work of the corn bill bug. One of the most characteristic things about a plant injured by the adult Southern Corn Bill Bug is the presence of transverse rows of holes across the leaves. At least three other insects in this State also eat rows of holes across the leaves. These are the larger cornstalk-borer, the corn ear-worm, and the adult of the Southern corn root-worm. The work of the Southern Corn Bill Bug may be distinguished from the work of these three insects by its greater regularity. (Fig. 7.) This is due, no doubt, to the fact that the corn bill bug works well down at the base of the stalk in the "bud," whereas the other insects work in the top in the unfolding leaves. Of these three, the work of the larger corn stalk-borers on the unfolding leaves resembles most closely the work of the corn bill bugs. The work of the stalk-borer is never quite so regular, however, as the corn bill bug's work, and frequently the rows of holes are only on one side of the heavy mid-rib, whereas in the case of the corn bill bug they are on both

sides of the leaves and usually they are of almost the same size and shape on both sides of the leaf. The holes eaten by the corn bill bug are nearly always with smooth round edges, as if they had been cut



FIGURE 5. Adult Southern Corn Bill Bug feeding on corn, normal position.

with a sharp punch, while the holes eaten out by the corn stalk-borer are usually decidedly more ragged. The holes eaten by the corn ear-worm are usually not round, but elongate and decidedly more irregular, on the average, than the holes made by the corn stalk-borer. The holes

eaten by the adults of the southern corn root-worm have a tendency to be square instead of being round. Not infrequently these beetles eat the tender leaves just above the seed leaf until the unfolding leaves are completely cut off. In this respect their work resembles the work of certain cut-worms, species not determined, which have the habit of



FIGURE 6. Adult female Southern Corn Bill Bug ovipositing in corn, normal position.

crawling up the stalk and cutting off the unfolding leaves. In all the fields examined, however, the work of the adult root-worms was much more common than the work of the cut-worms.

In general, farmers do not distinguish clearly between the work of the adult corn bill bugs on young corn and the work of the southern corn root-worm. The work of the corn root-worm is most conspicuous

about the time the corn is sprouting. At this time the seed leaf is vigorous and green and the unfolding leaves (bud) are withered and dead in those stalks that have been attacked by the root-worm. (Fig. 9.) On the other hand, in stalks attacked by the corn bill bugs all the leaves remain fresh and green at this time and later the whole plant dies if it is severely attacked. These young stalks usually show the characteristic rows of holes across the leaves. (Fig. 10.)

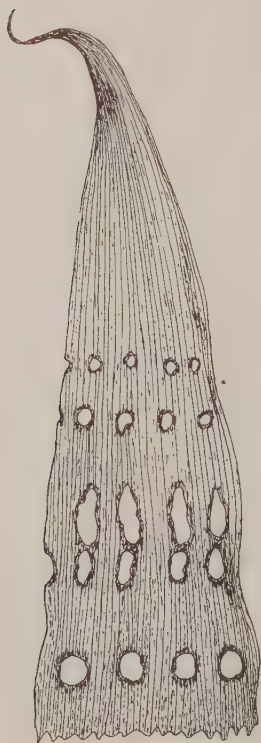


FIGURE 7. Portion of a corn leaf showing characteristic arrangement of feeding punctures.



FIGURE 8. Young corn stalk showing normal position of egg in heart, and egg more enlarged.

FOOD PLANTS

The following plants have been found infested with the corn bill bug. Corn, rice, and various species of cyperus as follows:

- Cyperus flaricomus*, at Raleigh and Willard,
- Cyperus cylindricus*, at Proctorville and Braswell,
- Cyperus strigosus*, at Lumberton and Chadbourn,
- Cyperus overlaris*, at Pembroke,
- Cyperus esculentus* (Chufa).

Of these plants, corn, rice, and chufas are infested wherever they are grown in the bill-bug section of the State, so far as we have observed. Of these plants, rice seems to be the favorite food where it can be secured, followed by chufas and corn. The reason for placing chufas ahead of corn is that around Raleigh, so far as observed, bill bugs are plentiful on chufas, but do not trouble corn even when they are growing side by side. The various species of cyperus will undoubtedly have to be considered as the native food plant of this species in spite of the fact that it has been reared from other grasses (Figs. 11, 12, 13).

According to Webster (1912), the following plants have been reported as food plants for this species from various parts of the country:



FIGURE 9. Young corn plant showing injury by Southern Corn Root Worm.



FIGURE 10. Young corn plant showing injury by Southern Corn Bill Bug.

“Dr. Forbes gives *Cyperus strigosus* as the natural food plant, in the roots of which it develops in Illinois. Mr. T. D. Urbahns found it developing in *Tripsacum dactyloides* at Plano, Tex., in July, 1909. At Appleton, Tenn., July 14, 1911, Mr. George G. Ainslie found the infested fields in part grown up with weeds and a swamp carex (*C. vulpinoides*), but he was unable to find the beetle actually developing therein. (See Pl. IX, figs. 1, 2.) Mr. A. N. Caudell reported the larvæ injuring the roots of yellow nut-grass (*Cyperus esculentus*) at Stillwater, Okla., in 1895. Dr. Chittenden reared the adult from a pupa found in the roots of *Panicum capillare* growing in low bottom-lands along the canal near Glen Echo, Md., in August, 1897. Mr. I. J. Condit found it breeding in Frank’s sedge (*Carex frankii*) growing on the Department farm at Arlington, Va. In Florida the insect develops from egg to adult in *Cyperus rotundatus*, while farther north, in the

Carolinas, the common food plant is the "chufa" (*Cyperus esculentus*). To such a degree is this true in the latter locality that the insect is supposed by farmers to have been introduced with that plant. Quite in accord with the foregoing, Mr. J. G. Sanders reared adults March 30, and again April 25, 1908, from *Cyperus exaltatus*, introduced from Egypt and growing on the Department farm at Arlington, Va."



FIGURE 11. Southern Corn Bill Bug larvæ in crown of Red Rooted Cyperus Grass. X $\frac{1}{2}$

LIFE HISTORY SUMMARY

The following summary is based largely upon observations made on the Pender Test Farm in the southeastern part of the State, but it is thought that the same conditions would be found practically throughout the area of greatest prevalence of the corn bill bug (Fig. 2). The adults hibernate over winter (Fig. 14), going into hibernation in late October (October 17th being the latest recorded date). They emerge

from hibernation in mid-April (April 10th being the earliest date recorded). Their numbers seem to increase rather rapidly until late May and after that rather slowly until mid-August. This increase is perhaps largely due to the fact that new adults are continually emerging from pupa whose larva have developed from eggs laid early in the spring. After mid-August the numbers of adults diminish rapidly, so that in early corn practically all the adults have disappeared by the end of August. A few adults remain active to late October. The adults commence to lay eggs by early May (May 5th being the earliest recorded date). The number of eggs found in the field increases rather rapidly until mid-June and then less rapidly until mid-July, the number of eggs falling off slightly toward mid-August. After which the number decreases rather rapidly. The latest date recorded



FIGURE 12. *Cyperus* Grass growing in a swamp to show characteristics.

for finding eggs in the field is September 23d, but as they were still rather common at that time, it seems safe to conclude that egg laying continues until early October, especially as the adults are active in the fields till late October. The distribution of the larvæ throughout the year seems to coincide rather closely with the distribution of the eggs. The earliest larvæ have been found in the field in mid-May, but the time of greatest abundance seems to be from late July to mid-August. After this time their numbers fall off rapidly, the latest larvæ being found in late October. (Larvæ in what appeared to be the fourth molt being found on October 27th.) The earliest pupæ have been found in late June. The number increases rather rapidly till late July and seems to remain nearly constant till late September; the latest pupa being found on November 9th. These late maturing pupæ seem to all change to adults before winter, and these adults seem to remain in the



FIGURE 13. Larva feeding on the roots of Cyperus Grass.

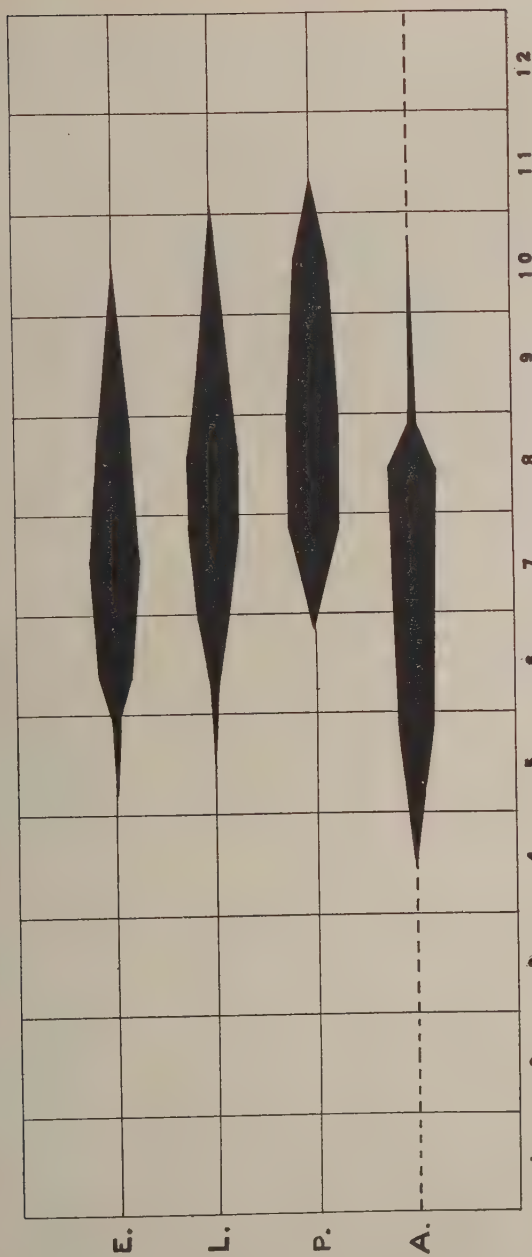


FIGURE 14. Life history summary. E. Eggs. L. Larvæ. P. Pupæ. A. Adults. The dotted line shows hibernation time. The figures at the bottom refer to the months.

pupal cells over winter, not becoming active until the following spring. There is some evidence to show that the early maturing adults lay eggs the same summer that they reach maturity, these eggs hatching and reaching maturity late in the season.

THE EGG DESCRIPTION

The egg is subreniform-elliptical in shape, almost pure white in color, and almost perfectly smooth (Fig. 15). As the egg grows older it becomes more yellowish. Its size varies greatly, as is indicated by the following table, which shows the lengths and greatest diameters of 51 eggs selected at random throughout the egg-laying season. The measurements were taken by means of a binocular microscope fitted with micrometer eyepiece calibrated to 0.0416 mm. Inasmuch as these eggs were selected at random throughout the season, they probably represent fairly average conditions for North Carolina. No constant differences between the sizes of eggs taken early in the season and those taken later in the season can be detected from the measurements.

MEASUREMENTS OF 51 EGGS OF THE SOUTHERN CORN BILL BUG—MEASUREMENTS TAKEN AT VARIOUS TIMES THROUGHOUT THE SEASON.

TABLE I.

Egg Number	Total Length, Measured as a Straight Line	Greatest Diameter
1	2.08 mm.	.95 mm.
2	2.91 mm.	1.03 mm.
3	2.08 mm.	1.03 mm.
4	2.36 mm.	1.03 mm.
5	2.95 mm.	.91 mm.
6	2.91 mm.	.91 mm.
7	2.50 mm.	.95 mm.
8	2.41 mm.	.95 mm.
9	2.33 mm.	1.03 mm.
10	2.54 mm.	.91 mm.
11	2.37 mm.	.86 mm.
12	2.50 mm.	.86 mm.
13	2.08 mm.	.95 mm.
14	2.28 mm.	.83 mm.
15	2.33 mm.	.83 mm.
16	2.45 mm.	.86 mm.
17	2.28 mm.	.86 mm.
18	2.95 mm.	.86 mm.
19	2.28 mm.	.91 mm.
20	2.24 mm.	.86 mm.
21	2.37 mm.	.99 mm.
22	2.50 mm.	.95 mm.
23	2.50 mm.	.99 mm.
24	2.24 mm.	.91 mm.
25	1.95 mm.	.98 mm.
26	2.41 mm.	.98 mm.
27	2.17 mm.	.70 mm.
28	2.46 mm.	.96 mm.
29	2.02 mm.	.88 mm.

Egg Number	Total Length, Measured as a Straight Line	Greatest Diameter
30	2.15 mm.	.90 mm.
31	2.54 mm.	.96 mm.
32	2.10 mm.	.93 mm.
33	2.21 mm.	.91 mm.
34	2.12 mm.	.91 mm.
35	2.19 mm.	.89 mm.
36	2.12 mm.	.91 mm.
37	2.05 mm.	.93 mm.
38	2.21 mm.	.92 mm.
39	2.28 mm.	.88 mm.
40	2.10 mm.	.88 mm.
41	2.19 mm.	.91 mm.
42	2.31 mm.	.91 mm.
43	2.57 mm.	.93 mm.
44	2.29 mm.	.85 mm.
45	2.27 mm.	.95 mm.
46	2.41 mm.	.91 mm.
47	2.18 mm.	.89 mm.
48	2.29 mm.	.87 mm.
49	2.54 mm.	.93 mm.
50	2.39 mm.	1.04 mm.
51	2.42 mm.	.93 mm.

THE EGG. TIME OF HATCHING

During the egg-laying period records have been kept of a total of 143 separate lots of eggs containing a total of 903 eggs. These eggs were hatched under varying conditions both as to temperature and moisture. Some of the eggs were hatched in pieces of cornstalks placed in vials or in tin boxes, and in some cases where there were large numbers of eggs they were placed in tin boxes together with the piece of corn on which they were laid. In some cases the records were secured to within four hours, in other cases to within not more than twenty-four hours.

These tables will show that there is great variation in the time of hatching of the eggs of the Southern Corn Bill Bug, and while the writer believes that this variation can be controlled to a very great extent by giving identical conditions, he also believes that no such uniform conditions exist in nature. Therefore, it seems perfectly safe to conclude that the eggs of the Southern Corn Bill Bug hatch in not less than 77 hours and that the time may be greatly extended certainly to 305 hours (Fig. 18), the mean time being 132 hours.

The figures in some of the tables are very accurate. This is especially true of the figures in Table II, where some of the figures are to within less than four hours.

In securing the figures for Tables III and IV the usual practice was to give the adults fresh food about 6 o'clock in the evening and then to remove this food about 8 o'clock in the morning. In most of the cases the eggs were examined about 8 o'clock in the morning, at noon, and

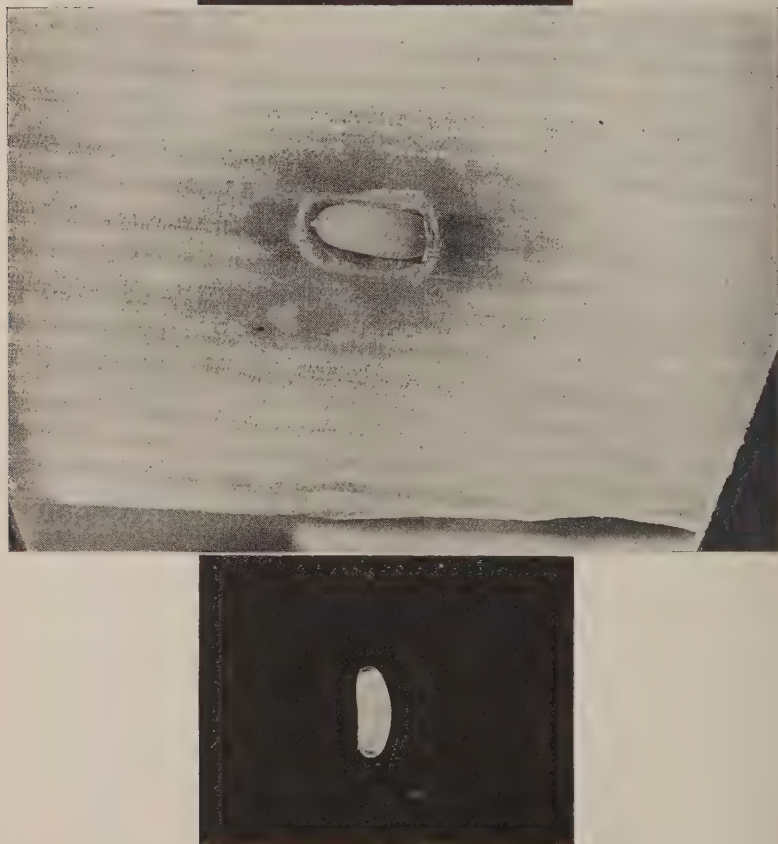


FIGURE 15. Egg of Southern Corn Bill Bug. X6. FIGURE 16. Egg of Southern Corn Bill Bug in natural position in pocket in outer leaf blade. X9. FIGURE 17. Larva of Southern Corn Bill Bug. Just hatched. X6.

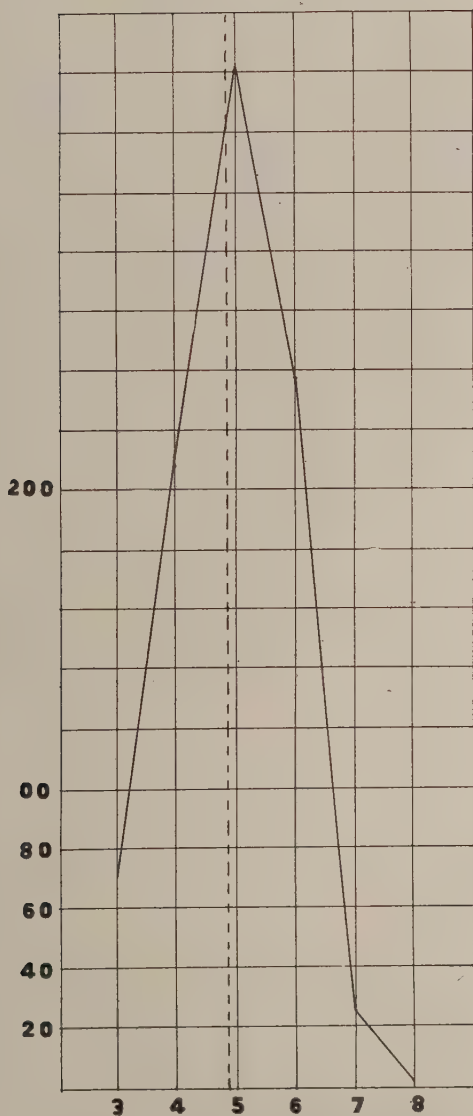


FIGURE 18. Curve to show time of hatching for 891 eggs of the Southern Corn Bill Bug expressed in one-day intervals. The mean time is shown by the dotted vertical line (.....).

again in the evening. In most of the cases, as will be seen from the above figures, the eggs hatched about noon on the fourth, fifth, sixth, and seventh days following the night on which they were laid.

Frequently eggs laid the same night in the same piece of corn and stored in the same tin box under what must obviously be the same conditions hatched at varying times from 102 to 174 hours.

This point was made a special issue for field experiment during the summer of 1914, and while no definite data could be secured, owing to the fact that the eggs were buried in the stalk where they could not be observed, yet females were watched ovipositing and the egg marked as carefully as possible and then examined three, four, five, six, and seven days later. Most of these eggs were laid in the morning between 5 and 8 o'clock and most of them were examined in the evening between 4 and 6; hence our results are not much closer than twelve hours. But out of twenty-three eggs examined in this way, fairly close time was secured on only six, the shortest observed time was 130 hours and the longest recorded time was 177 hours. The other four eggs that had hatched when examined and near which young larvæ were discovered were found in the evening of the sixth day after they were laid, giving a total time of about 154 hours from the time they were laid.

These figures agree very well with the figures as from the following tables.

TABLE II.

INCUBATION RECORD OF 53 LOTS OF EGGS HATCHED IN THE INSECTARY DURING THE SUMMER OF 1911.

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
1	6	151	161	156
2	1	150	160	155
3	2	156	160	158
4	4	168	178	173
5	1	174	184	179
6	1	188	195	192
7	1	193	205	199
8	2	170	183	177
9	1	170	183	177
10	1	158	169	164
11	1	150	166	158
12	5	123	147	135
13	5	141	165	153
14	4	127	151	139
15	1	186	192	189
16	26	148	164	156
17	5	139	143	141
18	1	305	329	317
19	4	137	141	139
20	3	161	165	163
21	1	141	142	142
22	3	161	163	162

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
23	5	144	159	152
24	1	137	139	138
25	2	148	150	149
26	5	132	147	140
27	6	145	160	153
28	12	145	165	155
29	1	162	164	163
30	3	120	144	132
31	1	144	168	151
32	1	159	161	160
33	8	146	167	151
34	1	129	150	140
35	1	210	216	218
36	2	159	164	162
37	5	223	247	135
38	10	148	172	160
39	5	144	168	156
40	6	141	173	156
41	4	128	147	138
42	4	142	165	154
43	23	147	158	153
44	3	132	142	137
45	7	141	151	146
46	2	144	160	152
47	10	128	144	136
48	8	151	172	162
49	6	137	144	141
50	22	136	143	140
51	11	139	143	141
52	13	96	120	108
53	3	94	118	106

TABLE III

INCUBATION RECORD OF 25 LOTS OF EGGS HATCHED IN THE INSECTARY DURING THE SUMMER OF 1913.

1	4	103	115	109
2	5	124	136	130
3	11	102	114	108
4	5	108	120	114
5	5	84	96	90
6	15	103	115	109
7	4	77	89	83
8	6	84	96	90
9	6	102	118	108
10	6	78	90	84
11	8	109	121	115
12	17	85	97	91
13	7	109	121	115
14	10	80	92	86
15	4	85	97	91
16	3	102	114	108
17	4	132	144	138
18	13	133	145	139

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
19	8	134	146	140
20	15	158	170	164
21	6	120	132	126
22	16	133	145	139
23	16	109	121	115
24	21	109	121	115
25	19	84	96	90

TABLE IV

INCUBATION RECORDS OF 65 LOTS OF EGGS HATCHED IN THE LABORATORY DURING THE SEASON OF 1915.

1	7	102	114	108
2	8	126	138	132
3	8	102	114	108
4	9	127	139	133
5	8	103	115	109
6	10	133	145	139
7	11	109	121	115
8	2	128	140	134
9	2	104	116	110
10	7	126	138	132
11	5	102	114	108
12	10	125	137	133
13	6	126	133	132
14	7	150	162	156
15	4	174	186	180
16	11	150	162	156
17	4	174	186	180
18	6	126	138	132
19	6	150	162	156
20	2	174	186	180
21	6	126	138	132
22	3	150	162	156
23	1	174	186	180
24	7	126	138	132
25	2	150	162	156
26	3	174	186	180
27	10	126	138	132
28	2	150	162	156
29	6	150	162	156
30	3	174	186	180
31	2	126	138	132
32	6	150	162	156
33	13	126	138	132
34	2	150	162	156
35	14	102	114	108
36	5	126	138	132
37	13	102	114	108
38	4	126	138	132
39	15	102	114	108
40	3	126	138	132
41	1	102	114	108
42	15	126	138	132

Lot No.	No. of Eggs	Number of Hours Required for Hatching		
		Minimum	Maximum	Average
43	6	102	114	108
44	6	126	138	132
45	3	102	114	108
46	4	126	138	132
47	2	102	114	108
48	8	126	138	132
49	1	102	114	108
50	11	126	138	132
51	12	126	138	132
52	10	126	138	132
53	5	126	138	132
54	5	150	162	156
55	8	150	162	156
56	5	126	138	132
57	4	150	162	156
58	7	150	162	156
59	8	102	114	108
60	3	126	138	132
61	7	102	114	108
62	4	126	138	132
63	6	126	138	132
64	3	150	162	156
65	2	126	138	132

WHERE LAID

Practically all of the eggs laid in the field are placed in the base of the cornstalk below the surface of the ground, or within an inch above the surface of the ground. In the cyperus plant the female seems to have a tendency to lay the eggs higher up. In young corn the eggs are usually laid deep in the heart of the stalk in especially prepared cavities (Fig. 8), but in older stalks the eggs are more frequently laid in the sheath of the outer blade, in a little pocket (Fig. 16).

Frequently in the field the eggs are loosely placed below the surface of the ground among the roots. In all cases where females had been watched closely they seemed to have a tendency to lay the last egg carelessly. In several cases where females had been observed to deposit one egg with the greatest care, the second egg was deposited in only a very shallow cavity or loosely among the roots. These females gave every evidence of being tired of the process of oviposition, and seemed to abandon all their usual precautions in egg laying.

Frequently, also, in our breeding cages loose eggs would be deposited. This tendency seemed to be greater when a layer of sand was placed in the breeding cages. So far as observed, these eggs seemed to be as fertile as eggs more carefully deposited. In no case where the female

deposited only a single egg was this egg deposited loosely, but always, so far as the writer's observations go, such eggs were deposited with the greatest care.

NUMBER LAID

The number of eggs laid by single females was the subject of a detailed experiment by Mr. Smith. The total number of eggs laid each day by 35 pairs as recorded by him is reproduced below in Table V. These records run from May 24th to September 29th. The daily egg-laying record of 23 pairs as recorded by the writer during the summer of 1914 is appended as Table VII. These records run from June 16th to August 24th.

In securing these records, single pairs were isolated in small jelly glasses and provided with a short section of cornstalk. These sections of cornstalk were cut from fresh stalks secured from the field every day, the sections being cut from the base of the stalk near the ground. In as far as possible, an attempt was made to secure food comparable to that found in the field. Towards the end of the season these stalks became hard and unsatisfactory for food, but they were always comparable to stalks found in the field.

In the field our records show that egg laying commences in early May, May 5th being the earliest date recorded at Willard. Egg laying continues through the season until September 21st in the field. But after August 15th the number of eggs diminishes very rapidly, owing perhaps to the fact that suitable corn cannot usually be found after that date. There is some evidence that the adults emigrate to cyperus from the cornfields late in the season, but the writer has never found eggs on cyperus after the middle of August. From these records it would seem that egg laying in the field actually surpasses our longest insectary record. This is perhaps due to the fact that insects brought from the eastern part of the State are set back in their egg laying, due, perhaps, to differences of temperature and moisture, and perhaps due to unnatural conditions during transportation. In part, the larger field record might be due to young adults which emerge in midsummer and lay a few eggs, but the fact that some of the adults in the insectary laid eggs as late as the 29th of September, at least a week later than eggs have been found in the field, would tend to minimize this factor.

According to our records, the greatest number of eggs laid in any single day was 11, and records of 5 to 10 are fairly common. The greatest number of eggs laid by any female, so far as observed, in the field, under perfectly natural conditions, was three eggs between 4:30 a. m. and 9:15 a. m. and then again in the evening between 6:30 and 7 she laid a single egg. In all, during the season of 1912 470 individuals were marked and observed for their egg-laying habits. None of these females were observed to lay eggs every day, but they were observed to lay often enough to lead one to conclude that they did lay

every day. Many individuals were observed to lay a single egg, and in one case one female was observed to lay an egg each day for three days in succession. Other individuals were observed to lay eggs on many separate occasions. Four individuals were observed to lay two eggs in the same day, these individuals being under almost continuous observation from 3:30 a. m. to 11 p. m.

From these observations it would seem safe to conclude that our daily egg records taken in the insectary would not be far from the conditions as they exist in the field; that is, that each female normally lays from one to at least four and perhaps more eggs each day from early May to late August, and perhaps more or less regularly from late August to late September.

TABLE V

EGG LAYING RECORDS

1911		Pair Number											
		1	2	3	4	5	6	7	8	9	10	11	12
May	24		4										
	25		1										
	26		1										
	27		1										
	28	3	3	0	5	0	2	5	5	1	1	5	5
	29	2	0	4	1	5	4	2	3	1	4	2	1
	30	2	2	0	1	1	1	3	2	0	1	0	4
June	31	4	3	1	3	4	4	4	3	2	1	0	3
	1	3	3	3	2	5	3	4	3	0	1	1	4
	2	4	4	3	4	7	3	4	4	1	1	4	4
	3	4	4	1	0	3	4	3	2	3	3	3	5
	4	1	4	4	3	6	6	3	5	0	3	4	3
	5	1	0	2	0	4	4	1	3	2	1	2	6
	6	3	5	5	0	6	3	3	1	0	4	7	5
	7	2	3	1	1	6	5	4	3	1	3	4	3
	8	1	3	2	0	3	4	1	2	0	0	4	5
	9	2	2	0	0	4	4	2	3	0	3	3	3
	10	1	3	3	0	3	3	1	0	2	4	3	6
	11	2	2	1	1	4	3	3	3	0	2	2	4
	12	4	3	3	1	9	3	2	2	2	5	5	6
	13	3	3	0	1	3	1	1	2	2	2	5	3
	14	3	4	3	3	6	0	1	1	1	0	3	7
	15	2	3	3	0	4	5	4	1	0	2	4	2
	16	1	4	4	2	7	6	0	2	1	4	5	8
	17	4	1	2	2	3	2	5	2	1	4	2	7
	18	2	3	2	0	4	4	1	2	1	1	6	1
	19	4	2	4	3	4	6	4	3	3	4	4	4
	20	2	3	2	0	5	5	0	2	2	3	5	4
	21	2	2	3	2	6	5	3	2	3	4	4	5
	22	2	4	2	1	5	3	1	2	2	2	2	4
	23	2	5	3	2	3	4	3	1	3	4	5	8
	24	3	3	4	2	5	7	2	4	3	4	5	1
	25	3	4	3	1	8	3	2	3	1	2	4	6
	26	4	4	4	2	6	7	2	3	2	3	6	5
	27	4	5	3	0	3	8	1	1	0	1	6	9
	28	2	6	3	3	6	5	0	4	3	1	3	4
	29	3	6	5	0	4	4	0	3	2	0	6	6
	30	2	4	5	1	2	6	2	2	3	0	5	2
July	1	2	4	6	2	4	5	0	2	2	0	2	4
	2	0	5	3	1	2	7	0	2	4	0	3	11
	3	1	5	6	0	3	5	2	1	2	0	6	5
	4	1	4	4	0	4	5	0	5	2	0	4	4
	5	0	3	2	1	4	3	1	4	2	0	4	6
	6	0	6	4	1	4	5	0	3	4	0	4	4
	7	1	3	2	0	3	3	1	3	1	0	7	8
	8	1	7	3	0	5	2	0	5	3	0	3	5
	9	2	5	3	0	4	5	0	2	3	0	5	5
	10	3	4	3	0	3	3	2	4	3	0	4	4
	11	1	6	3	0	1	8	0	2	1	0	3	4
	12	0	5	4	0	4	5	4	4	3	0	4	9
	13	2	6	1	0	5	1	1	4	3	0	4	9
	14	3	5	2	0	4	5	0	2	3	0	4	4
	15	3	3	2	0	2	3	0	2	2	0	5	5
	16	0	5	3	0	4	5	1	4	5	0	3	7
	17	0	5	3	0	6	4	0	3	3	0	6	6

TABLE V.

FOR 35 PAIRS, SUMMER 1911.

Pair Number																																		
13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35												
			1																	1														
			0		1						1				0	2				2														
			0		1						0				2	1				0														
4	2	0	1	4	0	5	2	4	1	4	0	1	2	0	0	2	0	0	5	0	0	0												
0	3	0	1	3	1	2	1	2	3	2	1	1	2	0	1	3	0	0	3	0	3	0												
2	1	0	0	4	5	2	0	0	0	1	2	3	2	0	1	0	0	0	0	0	0	0												
0	2	9	2	4	0	3	2	7	3	3	0	2	2	1	1	0	6	0	1	0	3	0												
3	2	4	1	4	2	4	2	3	1	2	1	1	2	0	3	2	0	3	2	0	0	0												
1	3	3	2	2	6	3	2	9	2	4	3	1	2	0	0	0	0	0	4	0	0	0												
2	1	3	0	3	2	3	1	4	1	1	1	0	2	0	1	0	2	0	2	0	0	1												
2	0	1	1	2	2	2	2	4	4	3	3	1	2	1	0	0	0	1	1	3	0	1												
1	1	4	1	5	1	1	0	0	1	3	5	0	1	2	0	1	0	0	0	1	0	1												
3	2	5	1	2	5	4	0	8	2	1	1	0	3	0	0	1	0	2	1	0	0	0												
1	2	2	4	2	1	0	1	4	2	1	0	0	0	0	1	0	0	0	0	0	0	1												
0	0	2	1	1	3	3	2	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0												
0	2	4	1	1	0	0	0	4	2	1	0	0	0	0	0	0	0	0	0	0	0	0												
2	2	4	1	0	5	3	1	6	3	1	0	0	0	0	0	0	1	0	0	0	0	0												
0	1	2	0	1	1	1	0	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0												
2	5	6	1	2	3	2	2	3	3	1	1	1	0	0	0	0	0	0	0	0	0	0												
1	3	5	1	2	3	3	1	1	3	2	1	0	0	0	0	1	0	0	1	0	0	0												
0	0	6	4	1	2	1	1	6	4	3	0	0	0	0	0	0	0	0	1	0	0	0												
1	1	4	1	0	2	1	0	1	2	3	0	0	0	0	0	0	0	0	0	0	0	1												
1	6	8	2	2	3	0	2	4	4	2	0	0	0	0	0	0	0	0	0	0	0	0												
0	2	7	0	1	5	0	0	5	3	3	0	0	0	0	0	0	0	0	0	0	0	1												
0	0	2	1	1	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0												
0	4	7	0	1	5	0	0	3	3	2	1	0	0	1	0	0	0	0	0	0	0	0												
0	2	6	2	0	2	1	1	4	0	3	1	0	0	0	0	0	0	0	0	0	0	0												
1	1	4	0	2	3	0	2	4	6	1	0	0	0	0	0	0	0	0	0	0	0	0												
2	3	5	0	0	4	1	0	3	2	3	0	0	0	0	0	0	0	2	0	0	0	0												
2	1	5	0	2	4	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0												
3	1	10	0	1	4	0	0	1	4	4	0	0	0	0	0	0	0	0	0	0	0	0												
1	3	5	0	4	2	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0												
2	4	9	0	3	5	0	0	3	4	1	0	0	0	0	0	0	0	0	0	0	0	0												
1	3	7	0	0	5	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0												
1	1	5	0	3	2	0	0	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0												
0	3	7	0	0	2	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0												
1	1	6	0	2	4	2	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0												
1	3	8	0	0	3	0	0	4	5	1	1	0	0	0	0	0	0	0	0	0	0	0												
0	2	5	0	0	3	0	0	2	4	2	0	0	0	0	0	0	0	0	0	0	0	0												
0	3	4	0	1	2	0	0	3	4	2	0	0	0	0	5	0	0	4	0	0	0	4												
1	2	4	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0												
0	2	7	0	0	2	0	0	4	5	1	0	0	0	1	0	0	0	0	0	0	0	0												
0	5	5	0	1	1	1	0	3	3	2	0	0	0	0	0	0	0	0	0	0	0	0												
0	4	0	0	0	0	0	0	3	4	1	0	0	0	0	0	0	0	0	0	0	0	0												
0	4	4	D	0	2	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0												
0	4	2	---	0	1	0	0	3	4	3	2	0	0	0	0	0	0	0	0	0	0	0												
0	3	6	---	1	1	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0												
0	5	3	---	0	0	3	0	5	6	2	0	0	0	0	0	0	0	0	0	0	0	0												
0	5	7	---	0	0	4	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0												
0	3	6	---	0	1	4	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0												
0	4	6	---	0	0	5	0	2	5	1	1	0	0	0	0	0	0	0	0	0	0	0												
0	4	3	---	0	0	5	0	2	5	2	0	0	0	0	0	0	0	0	0	0	0	0												
0	3	3	---	0	0	6	0	3	5	2	0	0	0	0	0	0	0	0	0	0	0	0												
0	2	3	---	2	1	4	0	3	4	1	1	0	0	0	0	0	0	0	0	0	0	0												

		Pair Number											
1911		1	2	3	4	5	6	7	8	9	10	11	12
July	18.....	1	7	4	0	3	3	0	6	4	0	4	6
	19.....	1	5	6	0	3	4	1	4	3	0	3	5
	20.....	0	2	7	0	2	7	0	4	3	0	1	3
	21.....	1	7	5	1	5	5	1	3	5	0	5	8
	22.....	0	4	8	0	2	7	2	2	4	0	6	2
	23.....	0	3	4	0	5	4	1	3	4	0	4	5
	24.....	1	6	5	0	3	2	1	5	5	0	6	4
	25.....	1	7	10	0	5	10	2	2	5	0	4	7
	26.....	0	1	3	0	1	3	1	1	3	0	5	2
	27-28.....	1	7	9	0	5	6	2	5	6	0	9	6
	29.....	0	7	7	0	4	5	2	2	3	0	5	1
	30.....	1	6	3	0	3	7	3	3	5	0	5	6
	31.....	1	3	4	0	3	2	3	3		0	3	3
August	1.....	1	8	6	0	6	8	1	0	5	0	6	2
	2.....	1	3	2	0	3	4	2	2	2	0	3	3
	3.....	1	5	4	0	3	1	0	2	4	0	7	0
	4.....	1	5	7	0	4	5	1	0	4	0	6	0
	5.....	0	6	3	0	3	4	1	2	2	0	4	0
	6.....	2	4	7	0	5	4	1	0	6	0	6	0
	7.....	0	4	7	0	4	4	0	0	2	0	8	0
	8-9-10.....	0	11	9	0	5	10	0	0	11	0	12	2
	11.....	0	4	6	0	1	4	0	0	3	0	6	0
	12.....	0	5	6	0	1	4	0	0	2	0	4	0
	13-14-15.....	0	13	8	0	5	11	0	0	4	0	10	2
	16.....	0	5	2	0	0	0	0	0	4	0	2	
	17.....	0	2	1	0	0	2	0	0	1	0	0	
	18.....	0	8	3	0	1	3	0	0	5	0	3	
	19.....	0	3	3	0	4	6	0	0	4	0	4	
	20.....	0	5	3	0	1	3	0	0	3	0	4	
	21.....	0	0	0	0	0	0	0	0	0	0	0	
	22.....	0	10	2	0	4	6	0	0	5	0	5	
	23.....	0	0	0	0	0	0	0	0	0	0	0	
	24.....	0	4	4	0	1	4	0	0	1	0	5	
	25-26.....	0	5	0	0	0	7	0	0	1	0	7	
	27.....	0	4	0	0	2	2	0	0	3	0	6	
	28.....	0	4	0	0	1	2	0	0	4	0	2	
	29.....	0	4	0	0	1	5	0	0	4	0	6	
	30.....	0	5	0	0	2	5	0	0	3	0	2	
	31.....	0	5	0	0	0	4	0	0	3	0	1	
September	1-2.....	0	7	1	0	4	5	0	0	5	0	6	
	3-4.....	0	7	7	0	3	4	0	0	6	0	6	
	5.....	0	2	2	0	0	1	0	0	1	0	3	
	6.....	0	5	0	0	0	5	0	0	2	0	0	
	7.....	0	2	0	0	0	0	0	0	4	0	0	
	8.....	0	3	0	0	0	1	0	0	2	0	0	
	9.....	0	5	0	0	0	1	0	0	1	0	4	
	10-11.....	0	7	0	0	1	3	0	0	1	0	2	
	12.....	0	4	0	0	0	0	0	0	0	0	2	
	13.....	0	1	0	0	1	0	0	0	0	0	4	
	14.....	0	0	0	0	0	1	0	0	0	0	1	
	15.....	0	1	0	0	0	1	0	0	0	0	0	
	16.....	0	2	3	0	1	2	0	0	0	0	0	
	17.....	0	0	0	0	0	0	0	0	0	0	0	
	18.....	0	3	0	0	0	1	0	0	0	0	0	
	19.....	0	1	0	0	0	1	0	0	0	0	1	

		Pair Number											
1911		1	2	3	4	5	6	7	8	9	10	11	12
September	20.....	0	1	0	0	1	1	0	0	1	0	1	
	21.....	0	0	0	0	D	0	0	0	0	0	0	
	22.....	0	0	0	0		0	0	0	0	0	0	
	23.....	0	0	0	0		0	0	0	0	0	0	
	24.....	0	0	0	0		0	0	0	0	0	0	
	25.....	0	0	0	0		0	0	0	0	0	0	
	26-27.....	0	1	1	0		1	0	0	0	0	0	
	28-29.....	0	0	0	0		1	0	0	0	0	0	
Totals.....		121	447	314	53	328	413	111	185	256	78	409	320

Pair Number

13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
0	0	---	---	0	0	---	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
0	0	---	---	0	0	---	0	1	0	0	0	---	---	---	---	---	---	---	---	---	---	---
0	0	---	---	0	0	---	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
0	0	---	---	0	0	---	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
0	0	---	---	0	0	---	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
0	0	---	---	0	0	---	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
0	0	---	---	0	0	---	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
0	0	---	---	0	0	---	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---	---
65	212	292	30	73	120	166	27	296	343	196	39	13	23	10	21	9	10	12	24	4	8	8

TABLE VI.
SUMMARY OF EGG LAYING RECORDS, BY MONTHS FROM TABLE V.

Pair Number	May	June	July	August	September	Totals
1	11	76	28	6	0	121
2	15	102	146	132	52	447
3	5	83	129	83	14	314
4	10	37	6	0	0	53
5	10	144	106	57	11	328
6	11	126	139	108	29	413
7	14	63	28	6	0	111
8	13	71	95	6	0	185
9	4	44	99	86	23	256
10	7	71	0	0	0	78
11	7	122	131	119	30	409
12	13	140	158	9	0	320
13	6	34	4	21	0	65
14	8	60	109	35	0	212
15	9	148	116	19	0	292
16	5	25	0	0	0	30
17	15	50	8	0	0	73
18	8	90	22	0	0	120
19	12	35	80	39	0	166
20	5	20	2	0	0	27
21	13	102	83	90	8	296
22	7	79	128	108	21	343
23	10	53	41	67	25	196
24	4	12	16	7	0	39
25	7	6	0	0	0	13
26	11	12	0	0	0	23
27	3	1	6	0	0	10
28	6	6	9	0	0	21
29	5	4	0	0	0	9
30	6	4	0	0	0	10
31	0	8	4	0	0	12
32	9	15	0	0	0	24
33	4	0	0	0	0	4
34	6	2	0	0	0	8
35	0	4	4	0	0	8
Totals-----	279	1,849	1,637	998	213	5,036

TABLE VII.

PAIRS NUMBERS 1 TO 23. COLLECTED ON PENDER

Eggs Laid		1	2	3	4	5	6	7
June	16.....	3	3	2	4	0	0	3
	17.....	2	4	2	0	0	0	1
	18.....	2	2	2	2	0	0	5
	19.....	0	1	1	1	0	0	4
	20.....	1	0	2	2	0	0	6
	21.....	2	2	2	1	1	0	6
	22.....	1	2	1	3	0	1	3
	23.....	2	2	2	1	0	0	1
	24.....	0	1	0	1	0	1	4
	25.....	2	4	0	2	0	1	10
	26.....	1	3	0	2	0	0	3
	27.....	1	5	0	7	1	0	2
	28.....	0	2	0	1	0	0	1
	29.....	3	3	0	2	0	1	5
	30.....	2	0	0	2	1	1	5
July	1.....	0	1	0	1	0	0	3
	2.....	0	0	0	1	0	0	1
	3.....	0	1	0	0	0	0	3
	4.....	2	3	0	8	0	0	9
	5.....	1	3	0	3	1	5	1
	6.....	0	2	2	0	0	1	0
	7.....	2	4	0	5	0	4	1
	8.....	3	2	1	4	1	5	8
	9.....	3	3	1	0	0	1	3
	10.....	1	1	0	5	0	1	8
	11.....	1	2	2	2	1	0	4
	12.....	3	2	0	4	0	7	11
	13.....	0	1	2	0	0	2	4
	14.....	4	1	2	3	0	2	7
	15.....	3	1	2	9	0	7	3
	16.....	4	3	3	7	0	2	4
	17.....	2	2	1	9	0	1	4
	18.....	3	0	6	5	0	3	7
	19.....	3	4	9	4	1	1	4
	20.....	1	1	0	0	0	2	0
	21.....	5	2	5	1	0	2	4
	22.....	4	5	7	6	0	3	5
	23.....	5	3	3	7	0	5	5
	24.....	8	3	6	11	0	0	7
	25-26.....	2	4	6	5	1	3	4
	27.....	4	3	5	5	1	3	2
	28.....	4	3	8	6	0	0	1
	29.....	4	0	5	4	0	3	1
	30-31.....	7	2	3	8	0	1	4
August	1.....	3	1	4	3	0	1	5
	2-3.....	5	*	6	8	1	0	4
	4.....	5	2	5	4	1	3	4
	5.....	6	1	3	6	1	5	4
	6.....	2	2	4	3	0	3	1
	7.....	5	2	3	6	0	3	5
	8.....	4	2	4	7	1	2	4
	9-10.....	7	4	6	1	1	0	1
	11-12.....	3	3	4	5	0	2	6
	13.....	3	2	0	9	1	7	2
	14-15.....	8	1	0	2	2	1	2

*Ants.

TABLE VII.

TEST FARM, JUNE 13, 1914—ISOLATED JUNE 15, 1914.

8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
5	4	0	0	2	0	7	0	0	2	0	2	5	2	7	3
2	1	0	0	2	1	3	6	0	1	0	1	4	1	2	8
2	4	0	1	3	2	2	0	0	0	0	1	6	1	6	2
1	1	0	6	3	1	2	3	1	3	0	2	4	0	2	4
1	1	0	0	0	0	2	0	0	2	0	2	4	0	1	2
0	3	0	0	0	3	1	3	0	0	0	2	1	3	2	4
2	1	0	2	3	2	2	1	0	1	0	1	4	0	5	1
3	0	0	0	1	3	3	1	0	0	2	2	5	0	5	2
2	1	0	1	4	1	0	1	0	0	0	2	1	0	1	2
1	0	0	0	2	4	4	0	0	3	0	1	5	0	2	0
0	0	0	0	5	4	2	3	0	0	1	1	5	0	7	4
0	0	0	2	12	12	2	8	0	0	0	1	4	0	2	2
2	0	0	2	3	3	3	1	0	1	2	0	7	0	3	4
0	1	0	1	5	4	2	3	0	0	0	2	4	0	†	4
1	0	0	3	0	2	0	1	0	0	8	1	1	0	5	3
0	0	0	3	1	5	0	1	0	0	0	2	4	0	3	2
0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0
0	0	0	2	1	0	0	0	0	0	0	0	0	0	3	0
1	0	0	6	4	3	1	4	0	0	0	0	5	0	7	3
1	0	0	7	2	0	0	1	0	0	3	1	3	0	1	2
0	1	0	1	2	1	0	0	0	0	0	2	0	1	2	2
0	0	0	3	4	3	0	3	0	0	0	0	3	1	3	4
1	2	4	7	5	3	0	1	0	0	0	1	4	0	4	2
2	1	3	4	5	4	1	3	0	2	4	1	5	3	6	4
5	0	2	4	3	1	1	1	0	0	0	0	3	1	6	4
2	0	2	2	2	3	2	2	0	0	4	3	8	3	3	3
3	1	4	3	4	5	1	6	0	0	2	2	3	4	5	2
3	0	4	2	2	1	2	2	0	1	1	2	1	0	2	2
2	0	6	1	6	2	2	4	0	0	†	†	†	5	5	6
2	0	7	6	7	3	1	1	1	0	0	2	4	5	6	1
3	3	4	4	3	6	1	1	0	0	0	0	0	2	6	4
1	8	3	2	3	4	0	0	0	1	0	0	0	1	2	0
3	5	8	1	4	4	3	1	0	0	0	0	4	3	5	2
2	6	5	6	3	1	2	1	0	2	0	1	4	4	4	1
0	1	3	0	4	1	0	0	0	0	0	0	0	0	0	0
2	4	2	2	2	2	3	0	0	0	0	0	0	2	5	5
2	7	6	0	2	2	4	0	0	1	0	0	1	5	1	4
4	4	6	5	9	5	4	0	0	1	0	0	2	2	3	1
4	9	5	5	1	1	3	0	0	1	0	4	1	2	0	5
1	0	7	5	4	6	3	0	0	3	1	1	5	0	4	4
1	7	4	2	3	3	0	0	0	1	0	2	0	1	1	4
0	4	2	0	5	3	7	0	0	5	0	1	1	1	2	2
0	3	5	3	0	4	3	0	1	5	0	3	1	1	2	4
1	12	9	2	2	0	13	0	1	8	0	0	8	3	0	2
0	3	3	5	8	3	4	0	1	3	0	3	1	2	5	4
0	9	7	1	2	3	1	0	3	4	0	0	3	2	2	1
0	9	7	2	3	0	4	0	1	0	0	3	4	3	3	7
0	3	4	1	3	2	3	0	1	0	0	2	0	4	2	3
0	5	5	3	5	3	2	0	2	0	0	3	0	2	4	3
0	4	5	3	4	5	5	0	2	6	0	0	6	4	2	3
3	4	4	6	5	3	2	0	1	1	0	1	3	0	4	2
1	2	10	3	1	5	9	0	1	3	1	0	9	7	5	3
1	4	11	2	9	2	5	0	2	5	0	0	5	7	4	2
5	7	7	9	4	3	2	0	1	5	0	0	5	6	7	2
0	0	4	7	0	4	1	0	1	0	0	0	2	3	2	2

†Without food.

Eggs Laid		1	2	3	4	5	6	7
August	18.....	10	3	3	3	1	0	9
	20.....	0	0	3	1	5	3	2
	24.....	0	1	0	0	0	3	0
Totals.....		162	120	137	211	23	102	229

8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2	4	2	3	10	2	0	1	0	0	0	1	2	0	0
0	8	1	1	2	4	0	0	2	0	0	0	5	1	0	0
0	9	0	1	1	4	0	0	0	0	0	0	0	5	0	4
79	164	173	153	188	169	132	64	23	71	43	61	174	106	179	151

TABLE VIII.

SUMMARY OF EGG LAYING RECORDS, BY MONTHS FROM TABLE VII.

Pair Number	June	July	August	Totals
1	22	79	61	162
2	34	62	24	120
3	14	78	45	137
4	31	122	58	211
5	3	6	14	23
6	5	64	33	102
7	59	121	49	229
8	22	46	11	79
9	17	78	69	164
10	0	101	72	173
11	18	89	46	153
12	45	93	50	188
13	42	76	51	169
14	35	57	40	132
15	31	33	0	64
16	1	3	19	23
17	13	31	27	71
18	13	15	15	43
19	21	28	12	61
20	60	70	44	174
21	7	51	48	106
22	50	89	40	179
23	45	70	36	151
Totals.....	588	1,462	864	2,914

WHEN THE EGGS ARE LAID

There are two main periods of oviposition during the day, just as there are two main periods of other activities. These two periods center around 8 o'clock in the morning and 6 o'clock in the evening. In a large field where the bill bugs are very prevalent adult females can be found laying eggs almost any hour of the day or night. But adults laying eggs are much more abundant at the periods mentioned and are comparatively rare or sometimes seemingly wanting from about 12 o'clock noon until 3 in the afternoon and again from about 12 o'clock midnight to 5 in the morning. A fuller discussion of the daily activities of bill bugs is to be found under the heading "Diurnal Activities" below.

HATCHING

As the young larvæ develop within the egg their form gradually becomes more and more evident until it is fully outlined. Then the egg-shell seems to split just as if the developing larva was too large for it. The larva may actually eat its way out, but close examination of many egg-shells failed to give any evidence that this was the case. One example was watched while hatching and the splitting of the egg-shell seemed to be due to the active wriggling of the larva. If

the egg-shell is actually eaten away by the larva, that fact could not be seen with the aid of a binocular microscope giving a magnification of 74 diameters.

Soon after hatching, the young larva commences to eat a tunnel downward and toward the center of the stalk.

PERCENTAGE OF EGGS HATCHING

During 1915, 37 different lots of eggs, making a total of 566 eggs, were watched in the insectary to determine the percentage of eggs that hatched. These eggs were placed in small tin boxes with sufficient green corn to give them plenty of moisture. Of the 566 eggs, 433 hatched, giving 76 per cent hatching. No reason can be assigned for the failure of the 24 per cent to hatch. All eggs that had not hatched by the end of nine days after laying were discarded and counted as not hatching, as they had usually molded by this time. No attempt has been made to compare this with conditions in the field, because no satisfactory method could be devised for watching the eggs under natural conditions.

TABLE IX.

36 LOTS OF EGGS OBSERVED IN THE INSECTARY DURING 1915 TO DETERMINE PERCENTAGE HATCHING.

Lot Number	Number of Eggs	Hatched	Not Hatched	Date Laid	
1	24	15	9	June	13
2	20	17	3		14
3	22	18	4		15
4	23	13	10		16
5	19	9	10		17
6	19	15	4		18
7	22	17	5		20
8	16	15	1		21
9	14	14	0		22
10	17	10	7		23
11	16	12	4		24
12	12	12	0		25
13	13	9	4		26
14	14	8	6		27
15	19	15	4		28
16	21	19	2		29
17	17	17	0		30
18	21	18	3	July	1
19	19	16	3		2
20	13	12	1		3
21	14	7	7		4
22	13	10	3		5
23	15	12	3		6
24	15	12	3		7
25	13	10	3		8
26	11	10	1		9
27	9	8	1		10
28	14	9	5		11
29	11	7	4		12
30	14	11	3		13

Lot Number	Number of Eggs	Hatched	Not Hatched	Date Laid	
31	27	21	6	July	14-15
32	9	7	2		16-17
33	13	11	2		18
34	10	6	4		19-20
35	11	9	2		21
36	6	2	4		22
Totals.....	566	433	133		

THE LARVA DESCRIPTION

The larva of the Southern Corn Bill Bug is a fleshy footless grub with a yellowish brown head, much larger posteriorly (Figs. 19-22). The different molts are practically identical, there being no important differences save size. Length from 2 to 11 mm., depending upon the molt; soiled white; head yellowish brown; trophi darker, almost black; body fusiform, strongly curved, swelling ventrally from the third to the fifth abdominal segments, then recurved and rounding to the anal extremity. Head large, hemispherically oblong, longer than broad; epicranial suture distinct, continuing as a shallow impressed sulcus on the frons: a faintly indicated undulating line either side of the epicranial suture starting on the vertex and ending on the frontal sutures; frontal sutures distinct sinuate; epicranium with eight hairs either side of the epicranial suture arranged as shown in Fig. 23; frons with four hairs either side of median line as shown in Fig. 23; four shorter hairs on the clypeal margin; antennæ rudimentary; clypeus free, transverse trapezoidal, sides converging ventrad; labrum smaller, semicircular, bearing a row of four long medial, four short submarginal, and eight shorter marginal hairs on the ventral curved margin, two prominent curving sulci either side of middle, dividing the labrum into three sub-equal halves; mandibles stout, triangular, with two short hairs near the base; maxillæ stout with three prominent hairs, cardo small, stipes large, elongate, bearing a short palpus with two unequal globular joints and a fleshy lobe thickly studded with hairs, which is concealed by the labium; labium consisting of a large triangular mentum with a median excavation on the distal part, palpiger triangular with a deep median groove, labial palpi equaling the maxillary palpi of two joints, ligula triangular rounded; three pairs of prominent hairs on the mentum, one pair on the palpiger and two pairs of short stout hairs on the outer surface of the ligula. Thoracic segments distinct; prothorax longer and broader with a chitinated shield on the dorsum, a large oblong spiracle middle of the sides of the prothorax. A pair of rather prominent hairs dorsally with two smaller ones between, nearer the median line and in front of these two pairs near the anterior border.

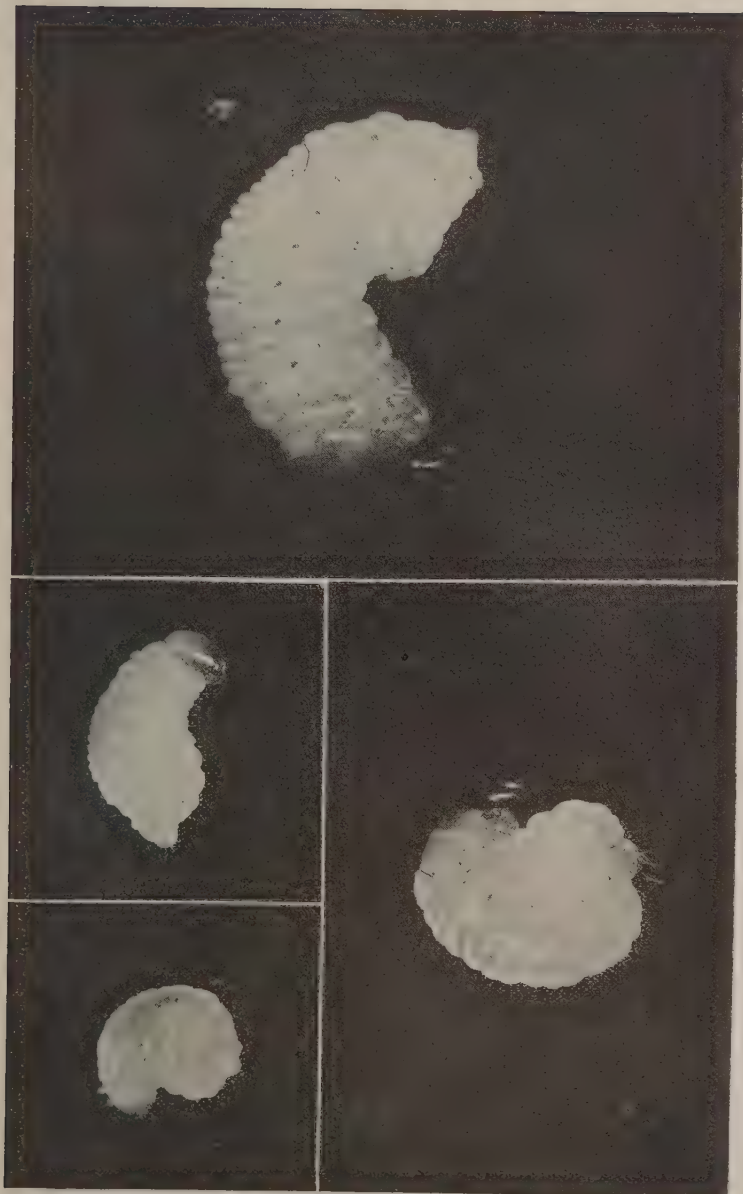


FIGURE 19. Larva just after first molt. X6.
FIGURE 20. Larva just after second molt. X6.

FIGURE 21. Larva just after third molt. X6.
FIGURE 22. Larva just after fourth molt. X6.

Posteriorly to the prominent pair there is a group of three hairs above the spiracle and four on the fleshy ventral protuberance. There is a pair each of the dorsal lobes of the mesothorax and metathorax. Three hairs on the dorso-lateral lobe of the mesothorax and two hairs on the metathorax. A single hair on each of the lateral lobes, ventro-lateral lobes, and the fleshy ventral protuberance of both the meso- and metathorax. The ventral lobes of each thoracic segment are provided with a median pair of hairs.

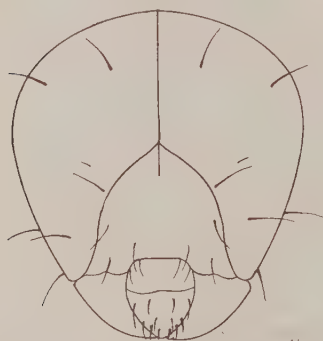


FIGURE 23. Frontal view of head of larva to show arrangement of hairs.

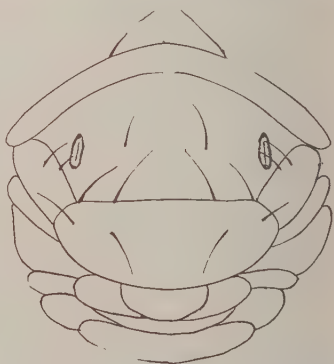


FIGURE 24. Seventh, eighth, and ninth abdominal segments of larva to show arrangement of hairs.

Abdominal segments forming, on the dorsum a narrow transverse fold, separated by two wider folds; the eighth and ninth abdominal segments excavated above without dorsal folds; ventrally the first three segments contracted, the succeeding segments enlarged; laterally each segment has numerous longitudinal folds; abdominal spiracles smaller than prothoracic pair, eight pairs; the first seven pairs situated just above the lateral folds, the eighth pair situated in the excavation of the eighth abdominal segment; the eighth pair larger than the other abdominal spiracles, equaling the prothoracic pair; all with chitinous margins of dark brown color.

Each abdominal segment from one to seven has a pair of dorsal hairs, a single hair on each lateral and ventro-lateral lobe.

The arrangement of the hairs on the seventh, eighth, and ninth abdominal segments is quite characteristic, and is shown in Fig. 24.

METHODS OF REARING LARVÆ

Several different methods have been used for rearing larvæ in the course of this investigation. Practically all of our larvæ have been reared on the portion of the main stem of the corn plant just above the roots. In placing them in these pieces of corn stem, they were at first placed in a small cavity hollowed out of one side. Later it was found that it was much easier to watch them from day to day if the piece of

cornstalk was split lengthwise, a small hollow large enough to receive the larvæ made in one piece and the two bound together with rubber bands. In this way the larvæ could be observed as often as necessary without undue disturbance, as the larvæ could usually be found in the central cavity which had been prepared for them.

Part of the larvæ have been reared in an out-of-door insectary (Fig. 25), and part have been reared in the laboratory (Fig. 28).

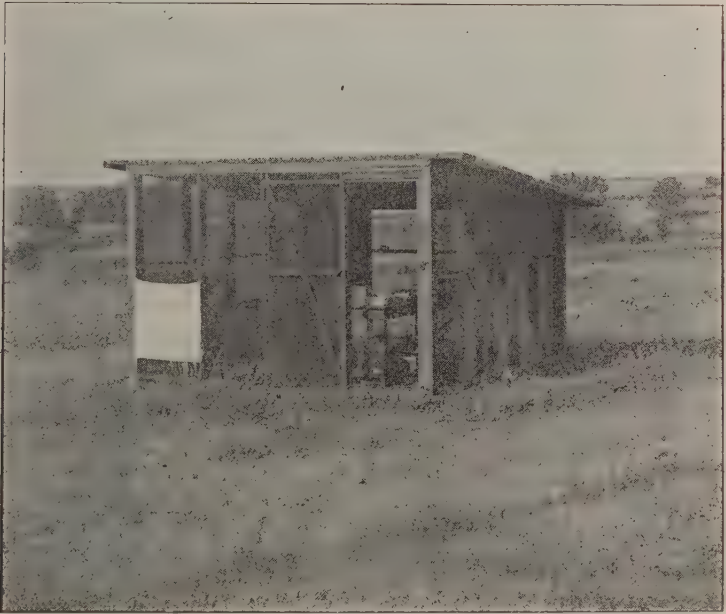


FIGURE 25. Insectary in which a part of the life history work on the Southern Corn Bill Bug was done. (After Smith.)

We have also reared larvæ in jelly glasses and in tin boxes, but of these two methods the tin boxes gave uniformly the better results and were much easier to handle. For this purpose we have used lately the Meyer's patent box, four-ounce size, which is provided with a permanent label on the lid (Fig. 27). This label was very convenient for making any records regarding the larvæ contained in the box, such as time and date of last observation, when last provided with food, date and time of molting, etc. Such records as were worthy of being permanently filed were put on sheets and filed in a vertical file. In this way there was no danger of confusing the record of one larva with another, and the complete record was always before the observer while examining any individual.



FIGURE 26. Hibernation cages used in the fields to determine the length of the hibernation period.

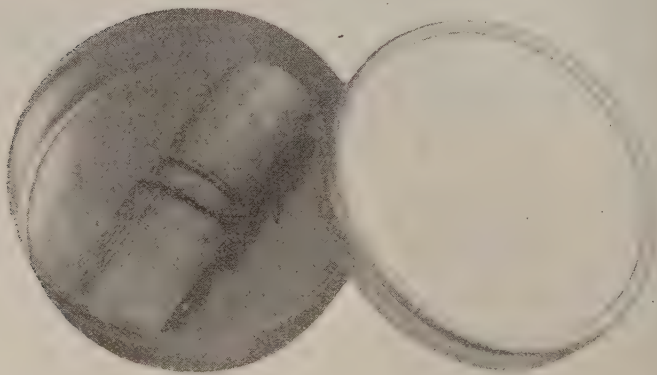


FIGURE 27. Tin salve box used in breeding the Southern Corn Bill Bug in the laboratory.

In the jelly glasses and in the tin boxes the pieces of cornstalk containing the larvæ were placed on and buried in damp soil, and placed on and buried in dry soil. Towards the end of the investigation all of these methods were discarded and the larvæ were kept in boxes without any soil. In this way there was no danger of losing the larva if it happened to abandon its piece of cornstalk.

By this method 192 larvæ have been reared from egg to adult and many other larvæ have been reared through part of their development.

Very careful records have been made of these larvæ; in many cases the exact hour when they hatched, or when they molted, has been recorded. For many cases, however, this has not been recorded; therefore, in the following records the time has been recorded only to the day. In most of this work two observations were made daily, one from about 8 to 10 a. m., the other from about 5 to 7 p. m. In this way the day was roughly divided into two periods approximating twelve hours each. Most of the changes, however, occurred at night and are recorded for the morning following the night on which they were made, and in a majority of cases, therefore, accurate to within twelve hours.

PROCESS OF MOLTING

The process of molting has been watched in several larvæ. Briefly, it may be described as follows: The larva first becomes somewhat stiff and loses its characteristic curved shape and becomes more or less straight (Fig 29). This usually precedes the actual molting an hour or two, but in some cases the larva commences to assume this attitude as much as eighteen hours before it actually molts. The older the larva the longer relatively this preliminary attitude seems to be. In the case of the last molt or change to the pupa it is frequently as long as two or three days (Fig. 30). While in this attitude the larvæ turns and twists about a great deal. This is especially marked as the mature larva prepares to pupate. In this way the inside of the pupal cell is smoothed and made compact, and this same result is noticed in the larval burrows, to a much less degree, however (Fig. 29).

The second step in molting is the splitting of the head. The old head gradually splits along the epicranial and frontal sutures, and gradually, as the larva turns and twists, the new head emerges and the old headpieces are worked posteriorly. The chiten covering the rest of the body is gradually worked backwards, and is left eventually in the burrow behind the larva. This chiten is very thin and evanescent and soon loses its identity, but the harder headpieces, particularly the mouth-parts, persist for a day or two. This whole process normally occupies about half an hour, but frequently the larva seems to become exhausted and to lie quietly for an hour or so before recommencing its interminable turning and twisting.

The head after molting is pure white, but in the course of an hour it commences to turn yellow and gradually it assumes the brownish

color characteristic of the larvæ between molts. This color is assumed very gradually, however, and frequently by close observation it is possible to distinguish a larva that has molted within the last twelve hours.

NUMBER OF MOLTS

In all, 221 larvæ have been raised from egg to pupal condition and many others have been carried through part of their development. Practically all of these larvæ evidently molted four times, but of this number only 93 were observed to make all their molts. A few indi-



FIGURE 28. Laboratory table arranged with trays for holding jelly glasses and salve boxes used in breeding the Southern Corn Bill Bug.

viduals, fourteen in all, molted five times and three of these molted six times. From these observations it seems safe to conclude that the normal number of larval molts is four.

Observations made on the above fourteen larvæ would lead one to believe that poor food would increase the number of larval molts. In one case the larva was purposely given poor food after its fourth molt. It molted six times. In another case a larva was purposely given poor food from the time it hatched, and it molted six times. Several



FIGURE 29. Larva preparing pupal cell. X6.



FIGURE 30. Larva just before fifth molt or pupation. X6

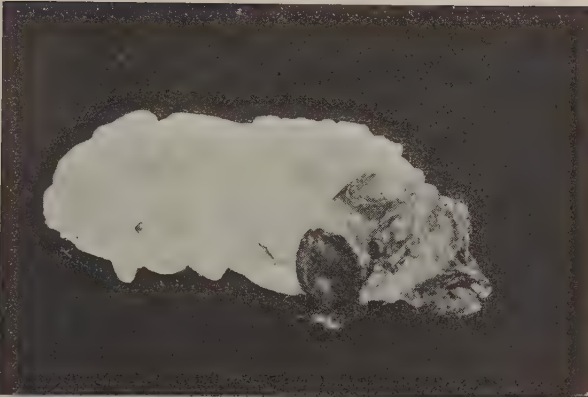


FIGURE 31. Pupa shedding larval skin. X6.

other individuals were tried in the same way, but we did not succeed in getting any more to pass through their stages, undoubtedly because the food was too poor.

In all our tables four has been taken as the normal number of larval molts, and all our calculations are based on these results. Whether the unnatural conditions of the insectary could have had any influence upon the number of molts is entirely beyond our power to determine. But, as will be pointed out in another connection, the writer believes that the conditions in the insectary as provided during these investigations was near enough natural conditions not to produce any unusual results.

It is obviously impossible to follow the number of molts of an insect such as the southern corn bill bug under perfectly natural conditions, as normally it lives within its food plant.

TABLE X. LARVAL DEVELOPMENT.

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
1	June 3	?	June 24	?	July 13	July 22	48
2	June 4	?	?	?	July 1	July 8	34
3	June 4	?	?	?	?	July 8	34
4	June 8	June 13	June 26	July 6	July 11	July 19	40
5	June 9	?	?	?	July 4	July 14	35
6	June 8	June 13	June 20	?	July 1	July 11	32
7	June 9	?	?	?	?	July 9	30
8	June 9	June 16	?	?	July 1	July 7	28
9	June 9	June 15	June 20	June 24	July 1	July 6	27
10	June 10	June 15	?	July 11	July 16	July 24	44
11	June 9	June 15	?	June 24	July 3	July 13	34
12	June 11	June 15	June 24	June 28	July 6	July 16	35
13	June 10	June 16	June 20	?	July 1	July 10	30
14	June 11	?	?	?	July 3	July 10	29
15	June 11	?	June 22	June 28	July 6	July 19	38
16	June 13	June 20	June 28	July 3	July 11	July 19	36
17	June 13	?	?	?	?	July 20	37
18	June 13	?	June 24	June 29	July 8	July 17	34
19	June 15	June 20	June 26	July 3	July 6	July 15	30
20	June 15	June 22	June 26	?	July 6	July 12	27
21	June 16	June 22	June 26	July 3	?	July 12	26
22	June 16	June 20	June 24	June 28	July 11	July 18	32
23	June 16	?	June 27	July 1	July 13	July 26	40
24	June 22	June 26	June 30	July 5	July 11	July 18	26
25	June 22	?	July 5	?	July 26	Aug. 7	47
26	June 22	June 29	?	?	July 11	July 22	30
27	June 22	June 29	July 3	July 12	July 20	Aug. 3	42
28	June 22	June 26	June 29	?	?	July 29	37
29	June 22	June 29	July 5	July 11	July 16	July 25	33
30	June 22	June 29	July 3	July 7	July 16	July 21	29
31	June 22	June 28	July 3	July 7	July 17	July 25	33
32	June 22	June 27	July 1	July 6	?	July 22	30
33	June 23	June 28	July 3	July 6	July 18	July 29	36
34	June 23	June 27	June 30	?	July 12	July 19	26
35	June 23	June 28	?	July 11	July 17	July 24	31
36	June 24	June 29	July 3	July 7	July 15	Aug. 17	54
37	June 26	?	July 5	July 11	July 15	July 25	29

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
38	June 26	July 1	July 6	July 11	July 17	Aug. 1	36
39	June 27	July 3	July 6	July 11	July 18	July 26	29
40	June 27	July 3	July 6	July 11	July 17	July 25	28
41	June 27	?	?	?	?	Aug. 3	37
42	June 27	?	?	?	?	July 31	34
43	June 28	?	?	?	?	July 26	28
43	June 28	?	?	?	?	July 26	28
44	June 28	?	July 12	July 17	July 26	Aug. 10	43
45	June 28	?	?	?	?	July 24	26
46	June 28	?	?	?	?	July 26	28
47	June 28	?	?	?	July 22	Aug. 2	35
48	June 28	July 4	?	?	?	July 27	29
49	June 29	?	?	?	July 23	Aug. 5	37
50	July 4	?	?	?	?	July 29	30
51	July 2	?	July 12	?	?	July 31	28
52	July 2	?	July 12	July 17	July 20	Aug. 5	34
53	July 5	?	July 17	July 22	July 26	Aug. 10	36
54	July 5	?	?	?	July 26	Aug. 6	32
55	July 7	July 13	July 17	July 20	?	Aug. 2	26
56	July 8	?	July 17	July 23	July 29	Aug. 10	33
57	July 8	?	July 19	July 23	July 29	Aug. 10	33
58	July 8	?	?	?	?	Aug. 7	30
59	July 8	?	July 19	July 22	July 27	Aug. 5	28
60	July 8	?	July 17	July 21	July 29	Aug. 10	33
61	July 12	?	?	Aug. 1	Aug. 10	Aug. 18	37
62	Aug. 3	?	?	Aug. 28	Sept. 5	Sept. 18	46
63	Aug. 7	?	Aug. 19	Aug. 24	Sept. 4	Sept. 12	36
64	June 2	?	?	?	?	July 14	42
65	July 8	?	July 17	July 24	July 31	Aug. 16	39
66	July 8	?	?	?	?	Aug. 11	34
67	June 10	June 16	July 20	July 1	July 5	July 13	33
68	June 9	?	?	July 8	July 11	July 19	40
69	June 22	?	July 5	July 16	July 18	Aug. 3	42
70	June 22	June 26	June 30	?	?	July 27	35
71	June 22	?	?	?	?	Aug. 14	53
72	June 23	?	?	?	?	July 20	27
73	June 26	July 1	?	?	?	July 31	35
74	July 24	?	?	?	?	Aug. 23	30
75	July 24	?	?	?	?	Aug. 26	33
76	Aug. 3	?	?	?	?	Sept. 11	37
77	Aug. 3	?	?	?	?	Aug. 26	23
78	Aug. 3	?	?	?	?	Aug. 26	23
79	Aug. 11	?	?	?	?	Sept. 6	26
80	Aug. 11	?	Aug. 27	?	?	Sept. 4	24
81	Aug. 28	?	?	?	?	Sept. 27	30
82	May 25	May 30	June 1	June 8	June 13	July 10	46
83	May 26	June 3	June 8	June 13	June 20	July 5	40
84	June 1	June 9	June 13	June 17	June 23	July 7	37
85	June 1	June 9	?	June 16	June 21	July 1	30
86	June 5	June 11	June 17	June 22	June 28	July 13	38
87	June 5	June 11	June 14	June 18	July 24	July 13	38
88	June 7	June 12	June 15	?	June 1	July 11	34
89	June 8	June 16	June 20	June 26	July 1	July 14	36
90	June 8	June 12	June 15	June 20	June 25	July 19	41
91	June 9	?	June 16	June 20	June 25	July 9	30
92	June 10	June 14	?	June 20	June 27	July 13	33

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
93	June 11	June 14	June 18	June 23	June 29	July 13	32
94	June 11	June 14	June 17	June 21	June 27	June 18	37
95	June 11	June 15	June 18	June 22	June 28	July 14	33
96	June 12	June 15	June 18	June 24	June 27	July 13	31
97	June 12	June 15	June 19	June 23	June 29	July 19	37
98	June 13	June 17	June 22	June 25	July 2	July 14	31
99	June 14	June 18	June 20	June 25	?	July 6	32
100	June 14	June 17	June 20	June 25	?	July 8	24
101	June 15	June 19	June 22	June 27	July 5	July 18	33
102	June 15	June 18	June 22	June 3	July 3	July 18	33
103	June 15	June 18	June 22	June 25	July 1	July 14	29
104	June 15	June 22	June 27	July 3	July 8	July 19	34
105	June 15	June 18	June 22	June 25	July 4	July 17	32
106	June 15	June 19	June 22	June 26	July 2	July 15	30
107	June 15	June 19	June 22	June 27	July 3	July 15	30
108	June 15	June 19	June 22	June 26	July 1	July 11	26
109	June 16	June 20	June 22	June 27	July 5	July 13	27
110	June 16	June 20	June 24	June 30	?	July 19	33
111	June 16	June 22	June 24	June 28	July 4	July 24	38
112	June 17	June 22	June 24	June 29	July 4	July 18	31
113	June 17	June 20	June 23	June 29	July 5	July 22	35
114	June 17	June 20	June 24	June 28	July 4	July 25	38
115	June 17	June 22	June 25	June 29	July 4	June 17	30
116	June 18	June 20	June 24	June 29	July 3	July 17	29
117	June 18	June 22	June 24	June 29	July 4	July 20	32
118	June 18	June 22	June 27	July 2	July 8	Aug. 1	44
119	June 18	June 22	June 26	July 1	July 8	July 24	36
120	June 18	June 22	June 27	July 1	July 8	July 21	33
121	June 18	June 22	June 25	June 25	?	July 14	26
122	June 19	June 22	June 27	July 2	July 11	July 24	35
123	June 19	June 22	June 25	June 29	July 6	July 20	31
124	June 19	June 22	June 25	July 1	?	July 19	30
125	June 19	June 22	June 28	July 3	July 9	July 19	30
126	June 19	June 23	June 27	July 3	July 11	July 24	35
127	June 19	June 22	June 27	July 1	July 7	July 20	20
128	June 19	June 22	?	July 2	July 10	July 22	33
129	June 19	June 22	June 28	July 2	July 8	July 21	32
130	June 19	June 22	June 27	July 2	?	July 25	36
131	June 19	June 23	June	July 1	July 8	July 22	33
132	June 19	June 22	?	July 1	?	July 15	26
133	June 19	June 22	?	July 2	July 8	July 22	33
134	June 20	June 24	June 28	July 2	July 9	Aug. 6	47
135	June 20	June 25	June 28	July 3	July 11	July 27	37
136	June 20	June 23	June 28	July 2	July 8	July 21	31
137	July 20	?	June 29	July 2	July 11	July 25	35
138	June 21	?	June 28	July 2	July 8	July 22	31
139	June 22	June 25	July 1	July 6	July 15	July 20	28
140	June 22	?	June 30	July 5	July 15	Aug. 3	42
141	June 22	June 28	July 8	July 15	July 18	Aug. 8	47
142	June 22	June 27	July 2	July 7	?	July 24	32
143	June 23	June 28	July 4	July 7	July 12	July 30	37
144	June 23	June 28	July 2	July 18	July 25	Aug. 7	45
145	June 23	July 1	July 4	July 11	?	July 27	34
146	June 25	June 28	July 9	July 11	July 20	Aug. 7	43
147	June 26	?	July 4	July 11	July 16	July 31	35
148	June 26	July 3	July 9	July 20	July 24	Aug. 6	41

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
149	June 27	July 1	July 4	July 11	July 17	Aug. 2	26
150	June 27	July 1	July 3	July 7	July 16	July 30	33
151	June 27	July 1	July 4	July 8	July 24	Aug. 3	37
152	June 27	July 1	July 5	July 12	?	July 24	27
153	June 27	July 1	July 4	July 9	July 24	Aug. 3	37
154	June 27	July 1	?	July 8	July 14	July 22	25
155	June 27	?	July 4	July 8	?	July 24	27
156	June 28	July 2	July 5	July 12	?	Aug. 5	38
157	June 28	July 2	July 5	July 9	?	July 21	23
158	June 28	?	July 5	?	July 21	July 30	32
159	June 28	July 2	July 7	July 12	?	Aug. 1	34
160	June 29	July 2	July 12	July 21	July 26	Aug. 10	42
161	June 29	?	July 5	July 12	July 22	July 26	27
162	June 29	July 3	July 12	July 17	July 26	Aug. 3	35
163	June 30	July 3	July 7	July 17	July 26	Aug. 3	34
164	June 30	July 3	July 8	July 20	?	Aug. 6	37
165	June 30	July 3	July 15	July 20	July 26	Aug. 9	40
166	June 30	July 3	July 8	July 17	?	Aug. 7	38
167	June 30	July 3	July 8	July 20	?	Aug. 3	34
168	June 30	?	July 8	July 15	?	July 31	31
169	July 1	July 10	July 15	July 22	July 27	Aug. 5	35
170	July 1	July 7	July 11	July 20	?	Aug. 14	40
171	July 1	July 9	July 15	?	?	July 30	29
172	July 2	July 9	July 15	?	?	Aug. 4	33
173	July 2	July 9	July 15	July 20	July 27	Aug. 12	41
174	July 2	July 5	July 12	July 15	July 21	Aug. 2	31
175	July 5	?	July 14	July 20	?	Aug. 2	28
176	July 5	July 9	July 15	July 22	July 30	Aug. 4	30
177	July 5	July 12	July 17	July 22	?	Aug. 6	32
178	July 5	July 9	July 15	July 18	July 26	Aug. 4	30
179	July 5	July 8	July 17	July 21	?	Aug. 4	30
180	July 5	July 9	July 15	July 22	?	Aug. 5	31
181	July 5	July 9	July 15	?	?	July 31	26
182	July 6	July 11	July 20	?	?	July 30	24
183	July 6	?	July 17	July 24	?	Aug. 10	35
184	July 7	July 16	July 18	July 26	Aug. 3	Aug. 14	38
185	July 7	July 12	July 17	July 26	July 30	Aug. 2	26
186	July 7	July 12	July 17	July 26	July 30	Aug. 8	32
187	July 7	?	July 20	July 26	?	Aug. 6	30
188	July 8	July 20	July 26	Aug. 2	Aug. 5	Aug. 18	41
186	July 8	July 14	July 20	July 26	?	Aug. 7	30
190	July 8	July 14	July 17	July 21	July 27	Aug. 9	32
191	July 8	?	July 22	July 22	July 30	Aug. 8	31
192	July 8	?	July 18	?	?	Aug. 2	25
193	July 8	July 15	July 18	July 22	?	Aug. 7	30
194	July 11	July 17	July 20	July 26	?	Aug. 6	26
195	July 11	?	July 20	July 26	?	Aug. 9	29
196	July 11	July 17	July 21	?	?	July 10	30
197	July 16	July 20	July 27	?	Aug. 4	Aug. 12	27
198	July 16	July 22	July 26	July 30	Aug. 6	Aug. 19	34
199	July 17	July 20	?	July 30	July 7	July 14	28
200	July 17	?	July 26	?	?	Aug. 14	28
201	July 17	July 21	Aug. 2	Aug. 8	Aug. 14	Aug. 29	43
202	July 17	July 21	July 27	?	?	Aug. 11	25
203	July 18	?	July 27	Aug. 2	Aug. 6	Aug. 25	38
204	July 20	?	July 30	Aug. 3	Aug. 7	Aug. 16	27

Record Number	Date of Hatching	Date of Shedding				Date of Pupating	Number Days Larval Stage
		1st Molt	2d Molt	3d Molt	4th Molt		
205	July 20	July 28	July 31	?	Aug. 6	Aug. 24.	35
206	July 20	July 24	July 31	Aug. 3	Aug. 11	Aug. 24	35
207	July 20	?	July 30	Aug. 4	?	Aug. 24	35
208	July 20	July 24	July 31	Aug. 2	Aug. 6	Aug. 24	35
209	July 22	?	July 31	Aug. 7	Aug. 14	Aug. 21	30
210	July 22	?	July 31	Aug. 3	Aug. 9	Aug. 20	27
211	July 22	July 26	?	Aug. 7	Aug. 11	Aug. 23	32
212	July 22	?	July 31	?	Aug. 9	Aug. 21	30
213	July 24	July 31	Aug. 4	?	?	Aug. 16	23
214	July 26	July 31	Aug. 4	Aug. 9	Aug. 14	Aug. 29	34
215	July 26	?	Aug. 2	Aug. 4	?	Aug. 26	31
216	July 26	July 31	Aug. 2	Aug. 6	?	Aug. 29	34
217	July 26	July 31	Aug. 2	Aug. 4	Aug. 7	Aug. 29	34
218	July 26	July 31	Aug. 2	Aug. 6	Aug. 11	Aug. 23	28
219	July 27	July 31	Aug. 2	Aug. 6	?	Aug. 18	22
220	July 27	?	?	Aug. 4	Aug. 9	Aug. 26	30
221	July 27	July 31	Aug. 4	Aug. 6	Aug. 12	Aug. 22	26

DURATION OF THE MOLTS

(First Molt, Fig. 19)

In all, 150 first molts have been recovered from the 221 larvæ that have been reared from the egg to the pupa. The duration from the date of hatching to the first molt ranged from two to twelve days, the extremes occurring once each. The greatest number, 105 out of the 150 or approximately 70 per cent, molted between the third and fifth day. This is expressed graphically by the curve (Fig. 32). From these figures it seems safe to conclude that usually the first molt occurs some time between the third and fifth day from the hatching of the egg, but it may be greatly prolonged, due, perhaps, in most cases to poor food, and first molts occurring six, seven, and eight days after hatching are not usual, and the first molt may occur as long as twelve days after hatching.

There is perhaps greater regularity in the occurrences of the first molt than there is in any of the succeeding molts, due, perhaps, to the fact that the larva has had less time than in its later molts to be influenced by its environment, especially by favorable or unfavorable food supply.

The other factor that cannot be neglected in this matter is the fact that any irregularities in the first or succeeding molts are of necessity cumulative, that is to say, the chances are that any larvæ that molt a few days early or a few days late in the first molt would also molt irregularly for the second and succeeding molts; hence these irregu-

larities would cumulate, and while individually they might be insignificant, yet when added to each other they have a tendency to throw our results away from the mean.

DURATION OF MOLTS

(*Second Molt, Fig. 20*)

There are two standards by means of which we may measure the duration of the second and succeeding molts. The first is the time that has elapsed since the first molt, and the second is the time that has

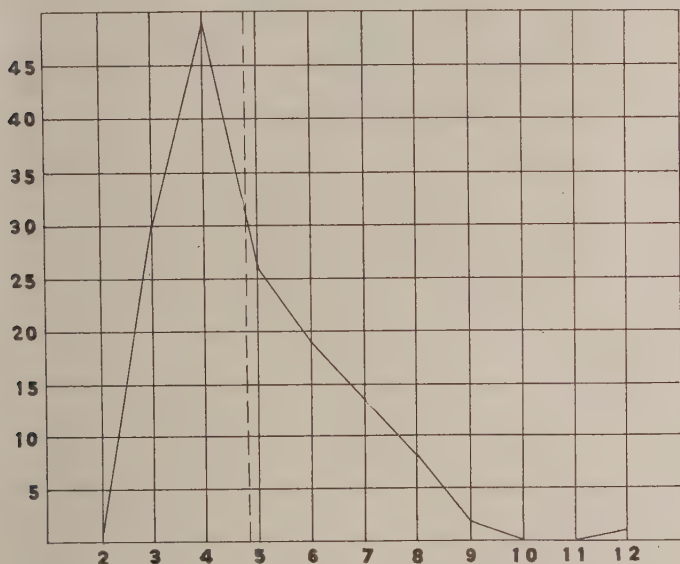


FIGURE 32. Curve showing the time lapsing between hatching and the first molt, one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).

elapsed since the egg hatched. Both of these methods have been used and the results expressed graphically by the attached curves (Figs. 33 and 34).

The time elapsing between the first and second molts is comparable to the time elapsing between hatching and the first molt, the range extending from 2 to 13 days. The majority, 106 out of 134 or a little more than 79 per cent, however, molted the second time from 3 to 6 days after the first molt.

The duration in days from the time of hatching to the second molt is not nearly as uniform as it is in the first molt, the range in 175 larvæ being 6 to 21 days. However, 140 larvæ out of the 175 observed molted a second time between the sixth and eleventh days, making a total of

80 per cent for six days, as contrasted with a total of 70 per cent in three days for the first molt. In the larvæ observed there was practically no difference in the numbers (thirty-one, twenty-four, twenty-seven, twenty-five, and twenty) molting on the seventh to eleventh days, inclusive.

DURATION OF MOLTS

(*Third Molt, Fig. 21*)

The range in time from hatching to the third molt for 165 larvæ out of 221 larvæ bred from egg to pupa has been found to be from 8 to 31 days. The majority, however, 103 out of 165 or 62 per cent, molted between the eleventh and fifteenth days, inclusive (Fig. 35), there being practically no difference in the numbers (eighteen, twenty-two, twenty-two, nineteen, twenty-two) molting on the eleventh and succeeding days to the fifteenth, inclusive.

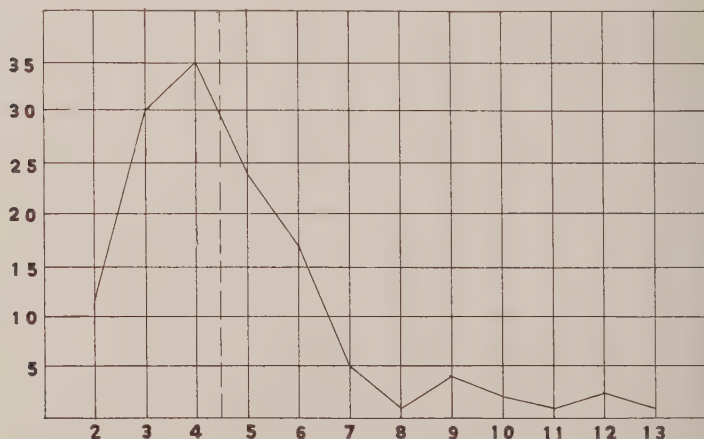


FIGURE 33. Curve showing the time lapsing between the first and second molts, one-day intervals. The mean time is shown by the dashed vertical line (---).

The time elapsing between the second and third molts is comparable to the time elapsing between hatching and the first molt and between the first and second molts, the range extending from two to sixteen days (Fig. 36). There was, however, only one larva out of 152 larvæ that required sixteen days between the second and third molts and none requiring thirteen, fourteen, or fifteen days. Hence this one larva may be discarded, giving us a range of from two to twelve days. These figures are very closely comparable to those found for the time elapsing between hatching and first molt and between first and second molt. In all, 115 out of the 152, or more than 75 per cent, molted for the third time between the third and sixth days after the second molt; the only

striking point being the larger number, 83 or more than 54 per cent of the total number, molted between the fourth and fifth days after the second molt.

DURATION OF MOLTS

(Fourth Molt, Fig. 22)

The time elapsing between third and fourth molts ranges from 2 to 15 days (Fig. 37). Ninety out of the 130 larvæ, or about 70 per cent, molted between the fifth and eighth days, inclusive. Six days in this case is more pronounced than in any of the other curves for lapsed time (see Figs. 32, 33, and 36).

The total time from hatching to the fourth molt ranges from 12 to 40 days, and there is a great tendency to variation (Fig. 38). The principal mode seems to occur around the nineteenth day.

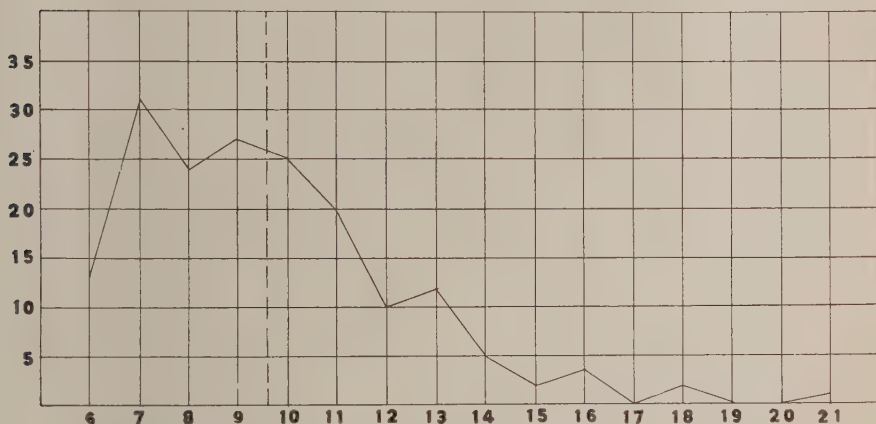


FIGURE 34. Curve showing the time lapsing between hatching and the second molt, one-day intervals. The mean time is shown by the dashed vertical line (— — — —).

DURATION OF MOLTS

(Fifth Molt, Fig. 30)

(From fourth larval molt to pupation.)

The time between the fourth larval molt and pupation (fifth molt) is decidedly longer than that recorded for previous molts, ranging from three to thirty-one days. For the 149 larvæ for which we have been able to obtain the fifth-molt interval, there seems to be a tendency for the results to group themselves around two modes, one at 8 days and the other at 13 days. The mean, however, is 12.4 days, suggesting that the latter is perhaps the true mode, and that the apparent mode at 8 days is due to insufficient numbers (Fig. 39).

The total time for larval development, *i. e.* from hatching to pupation, ranges from 22 to 54 days (Figs. 40 and 41). The majority,

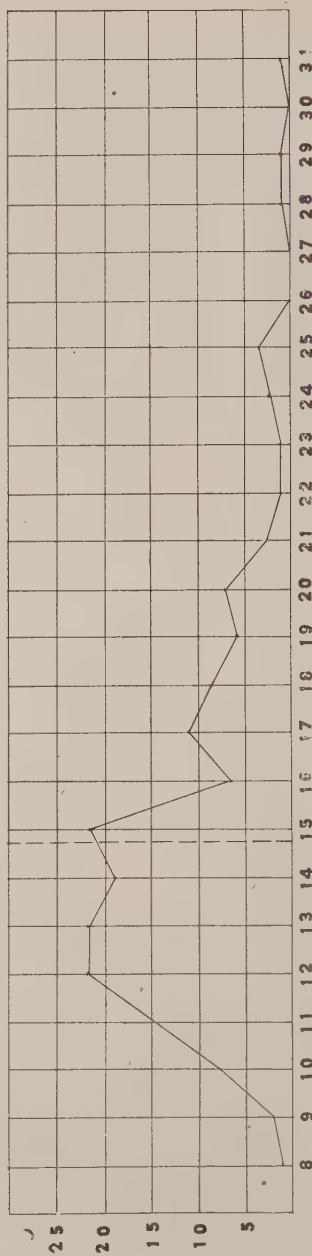


FIGURE 35. Curve showing the time lapsing between hatching and the third molt, one-day intervals.
The mean time is shown by the dashed vertical line (---).

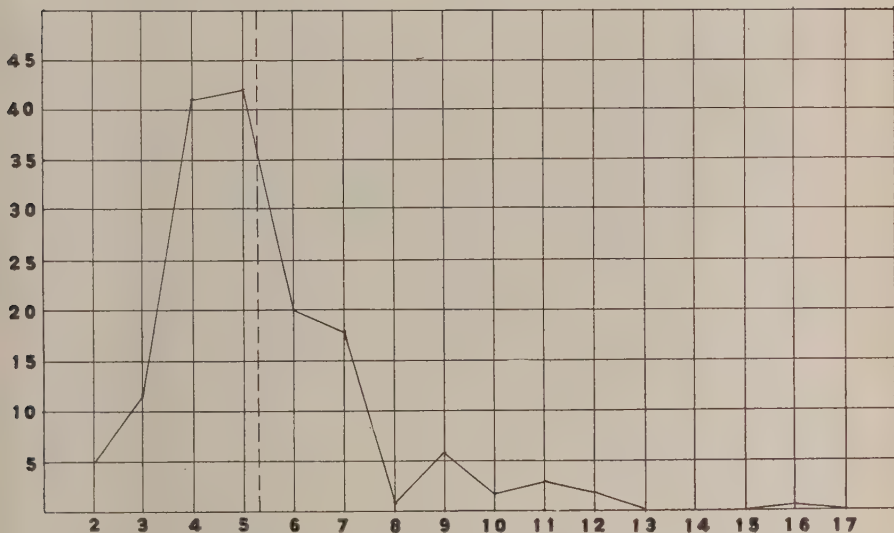


FIGURE 36. Curve showing the time lapsing between the second and third molts, one-day intervals. The mean time is shown by the dashed vertical line (— — — —).

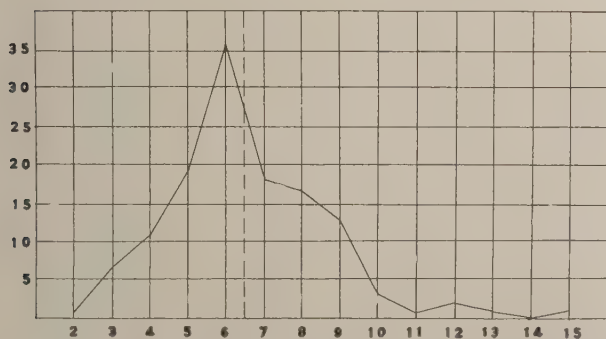
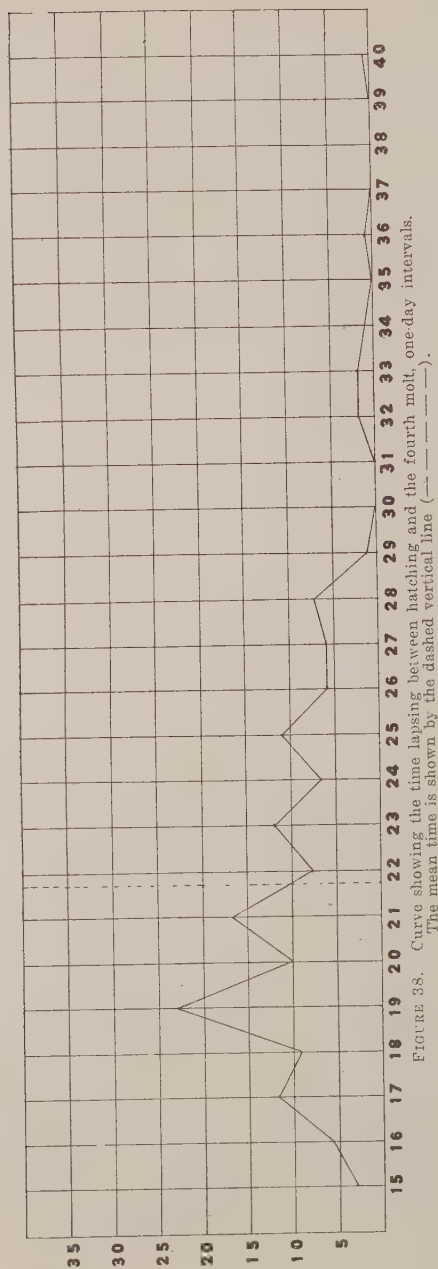


FIGURE 37. Curve showing the time lapsing between the time and fourth molts, one-day intervals. The mean time is shown by the dashed vertical line (— — — — —).



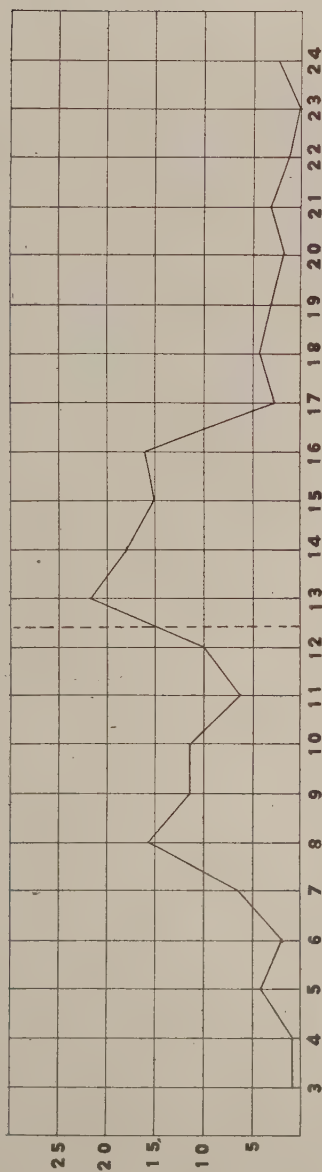


FIGURE 39. Curve showing the time lapsing between the fourth molt and pupation (fifth molt), one-day intervals. The mean time is shown by the dashed vertical line (---).

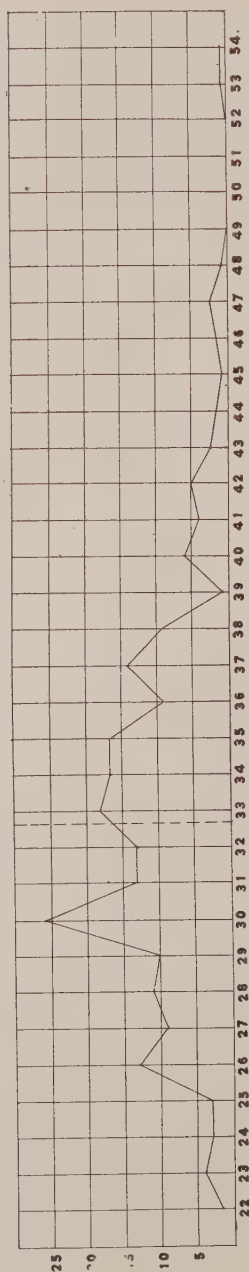


FIGURE 40. Curve showing the time lapsing between hatching and pupation (fifth molt), one-day intervals.
The mean time is shown by the dashed vertical line (— — — — —).

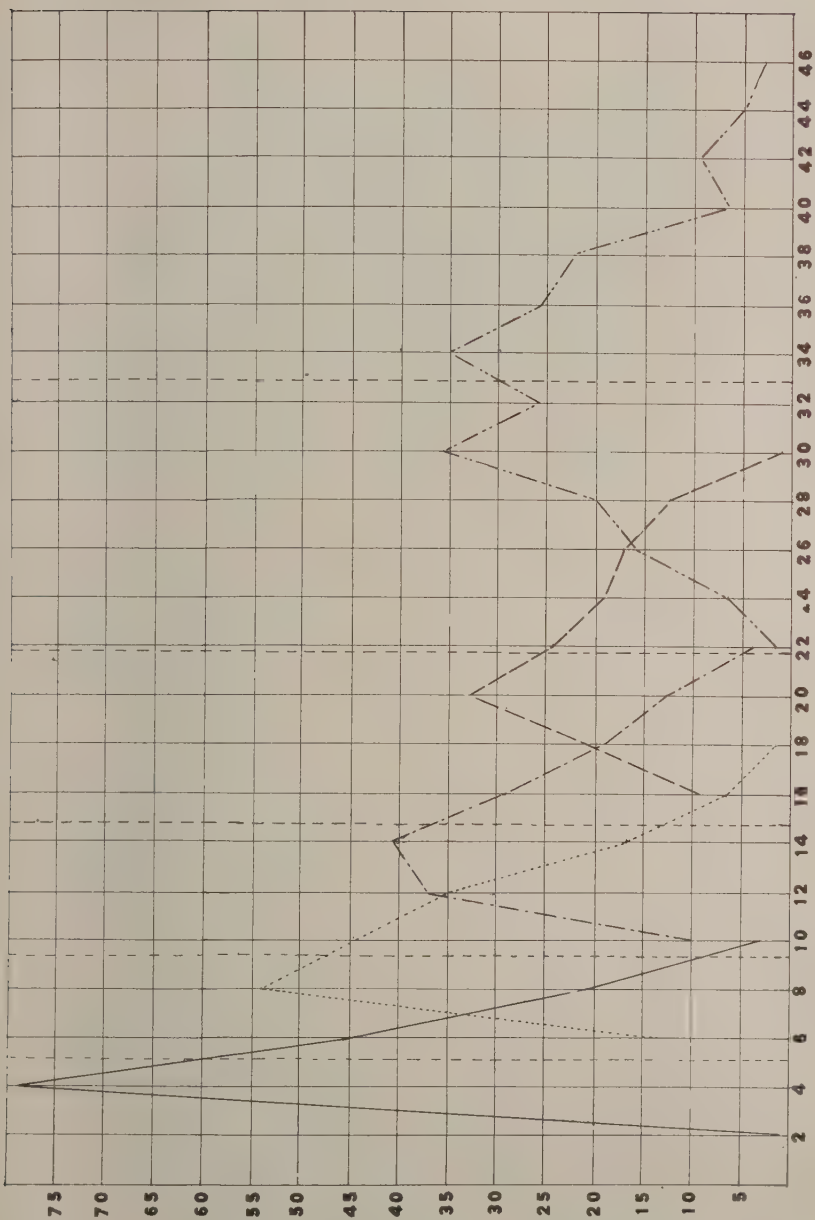


FIGURE 41. Curves showing larval development by molts, two-day intervals from hatching. Solid line first molt (—), Dotted line (.....) second molt. Dashed and dotted line (— · — · —) third molt. Dashed line (— · — · —) fourth molt. Dashed and dots (— · — · —) fifth molt. The mean time for each molt is shown by the dashed vertical lines (— · — · —).

however, 169 out of the 221 larvæ observed, or about 77 per cent, passed through their larval development between the 26th and 37th days after hatching.

CHARACTER OF INJURY CAUSED BY LARVÆ

The most noticeable result of the presence of the larvæ in stalks of corn is the stunting of their growth. Nearly always in fields of any size there are some stalks that escape injury, due to a variety of conditions, and these stalks always tower above their neighbors like giants among a group of pigmies. Stalks that have worms present early in their development usually are injured to such an extent that they die. Stalks that are attacked later may grow to a certain extent after the attack by the larvæ, but one usually has no trouble in deciding which stalks in a given field are infested by larvæ and which ones are not.

These secondary effects upon the stalks are found in the abnormal growth that the stalks make. In addition to being stunted, the stalks, in severe attacks, are twisted out of all semblance to a cornstalk. This usually results in an attempt to produce suckers, but usually these suckers are not able to expand their leaves, and appear like some great abnormal growth on the sides of the stalk. (Figs. 42, 43, and 44.)

When the larvæ are working externally around the roots (Fig. 45), they seem to produce a distinct scar or split which extends up along the side of the plant, often to a height of several inches above ground. These scars are frequently shallow, but often they are very deep and seriously retard the normal growth of the plant. They appear to be out of all proportion both in length and in depth to the actual injury caused by the larvæ.

Another source of injury directly attributable to the larvæ is the weakening of the stalks to such an extent that they are blown over by heavy winds. This is more noticeable in fields that are only moderately infested by corn bill bugs than it is in fields that are badly infested, due to the fact that badly infested fields do not produce stalks large enough to be blown over by the wind.

Internally the larvæ upon hatching from eggs deposited in the stalk seem always to take a course diagonally inward and downward toward the center of the stalk, coming to lodge eventually in the tap-root (Fig. 46). While the larvæ are small, they do not seem to injure the stalk to any great extent, but as they increase in size they frequently eat away the entire tap-root (Fig. 47). This, of course, results in the stunting of the growth of the plant as noted above. This internal injury is nearly always confined to the tap-root and the portion of the stem below ground. Occasionally larvæ after working downward to the tap-root, turn and work upward sometimes to a considerable distance above ground. The causes behind such behavior are difficult to determine, as it certainly is not always due to a lack of food, for frequently larvæ will work upward in stalks where there is an abundance of food

below ground, and again larvæ have been found in the tap-root where the entire root had been reduced to a dry reddish brown pulp. In some cases it appeared to be due to lack of moisture in the soil, as in all cases where the larvæ had been driven to feed above the ground the soil around the plant was very dry, whereas the stalk above ground was succulent and green. Whether this was the only factor is of course difficult to determine.

The writer believes that eggs laid loosely in the ground hatch into larvæ which feed externally on the roots and the stem below ground and do not enter the stalk. Some of these externally feeding larvæ may be from eggs that were laid in the stalk, the larvæ on hatching boring downward until they leave the tap-root, as it is not unusual to find stalks that larvæ have deserted in this way.

The larvæ, of course, always do much more damage to stalks of corn than the adults. This is exactly contrary to popular belief, due to the fact that the adults are more or less exposed and are more or less familiar to most farmers in the corn bill bug sections of the State, whereas the larvæ are hidden within the stalk and are not at all well known.

HABITS OF THE LARVÆ

Inasmuch as the larvæ work either in the stalk or among the roots in the ground, their habits are rather hard to follow consecutively.

The following notes are presented from a study of several hundred individuals collected in the field and from a more detailed study of the individuals reared in the laboratory.

The majority of larvæ seem to prefer to feed internally upon the tender growth just above the tap-root or in the tap-root itself. A considerable number of larvæ are to be found feeding externally upon the roots or the stem below ground. The writer believes that the larvæ that are feeding externally are larvæ that have hatched from eggs which have been dropped loosely, a habit adult females seem to have after they have laid a number of eggs in the same day.

The larvæ that hatch from eggs deposited in cavities burrow downward toward the center of the stalk, enlarging their tunnels as they proceed. When the stalk is young and tender they seem to consume practically everything in their tunnels as they come to it, but in the older stalks the larvæ tear off large pieces, which are reduced to frass and left in the tunnel behind them. As the larva grows older it seems to tear off proportionally more and more of the stalk than it can devour, so that usually by the time it is ready to pupate the larval burrow is pretty well filled with fragments of stalk in the immediate vicinity of the larva, and it is from these fragments that the pupal cell is constructed.

The larva is capable of comparatively rapid movements when disturbed, but normally it does not seem to move very far from the end



FIGURE 42. Corn plant showing characteristic stunting caused by larvae.

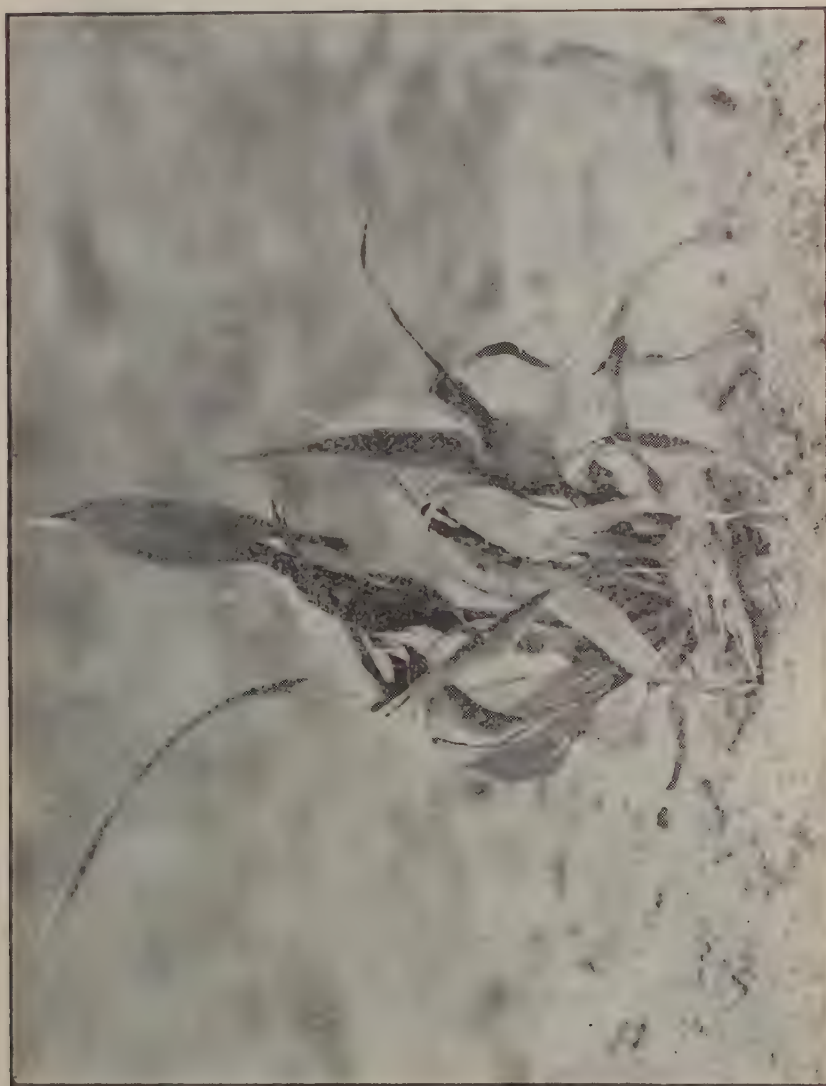


FIGURE 43. Corn plant showing damage caused by insect.

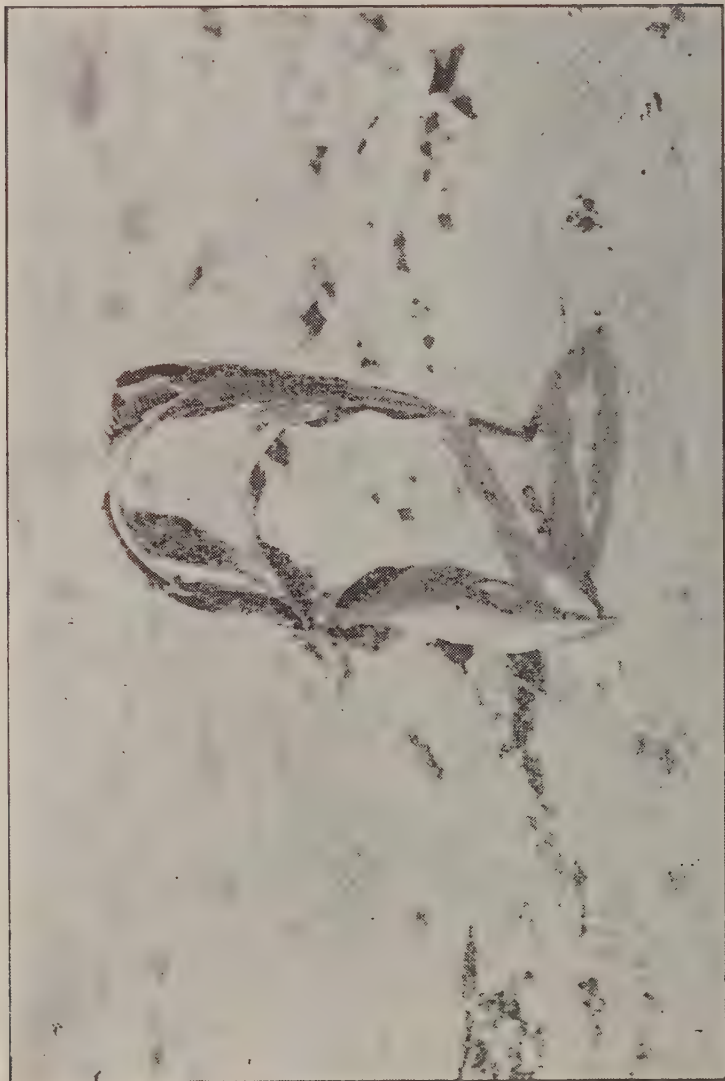


FIGURE 44 Corn plant injured by larvae.

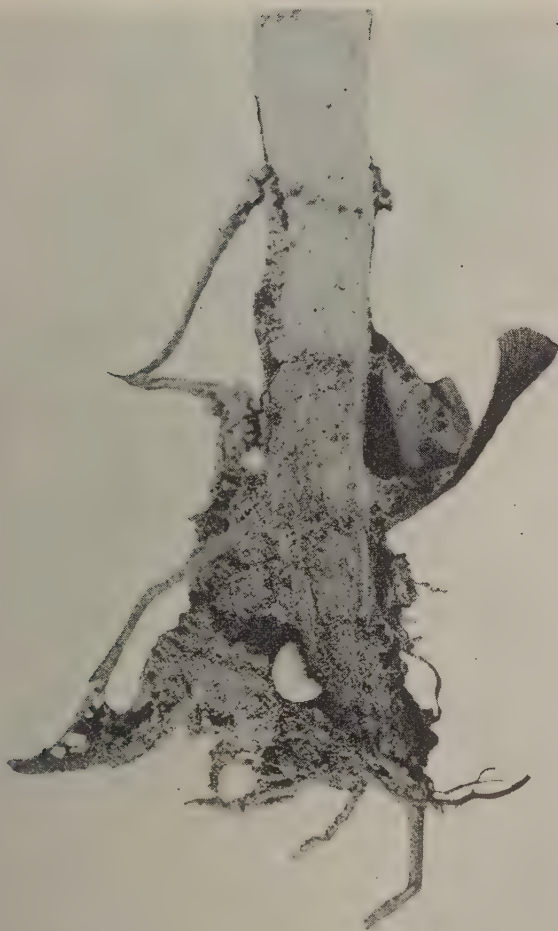


FIGURE 45. Larva working among the roots of corn.

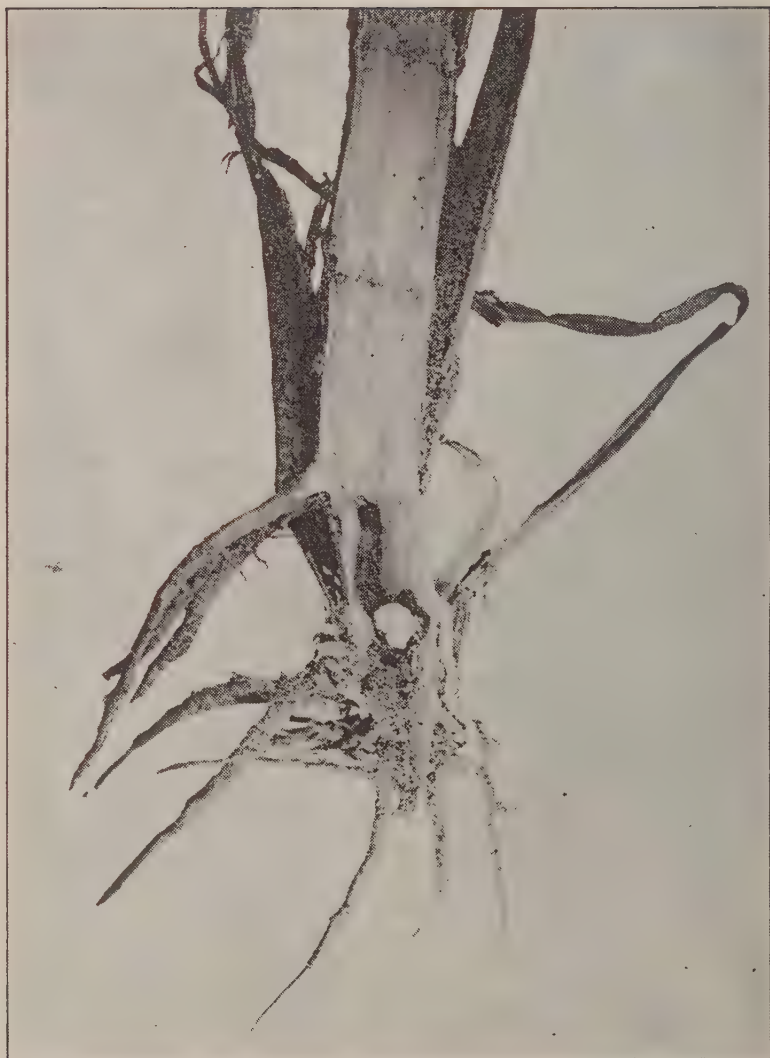


FIGURE 46. Larva in stalk of corn showing burrow.



FIGURE 47. Corn plant showing injury to tap-root by larva.

of its tunnel where it is feeding. In the insectary the larvæ in the first day or two after hatching are capable of constructing an enormous length of tunnel, comparatively speaking. It is nothing unusual for one of these small larvæ less than two milimeters in length to burrow four or five times the length of a section of cornstalk seventy-five milimeters in length in a single day, or more than one hundred and fifty times its own length.

The turning and twisting habits of the prepupal stage of the larvæ is given in the discussion of the formation of the pupal cells. The larvæ as they prepare to molt have the same habit of turning about in their burrows. This most certainly helps them very much in getting rid of the old cast skin, as the larvæ usually work themselves forward at the same time they are turning; thus they travel in a spiral, and the cast skins are gradually worked backward and left eventually in the tunnel behind.

MORTALITY DURING LARVAL STAGE

In our breeding cages we have tried, in as far as possible, to give the larvæ natural conditions and at the same time make it possible to observe the larvæ from day to day. This undoubtedly subjected the larvæ to conditions which must have been in part, at least, adverse to their best development. On the other hand, larvæ which were observed every day completed their development in the same average time as larvæ which were disturbed only as often as was necessary to provide them with fresh food.

During the summer of 1915, 265 larvæ were isolated and studied for mortality data. These larvæ were treated in the ordinary way for rearing larvæ save that they were disturbed only when it was necessary to give them fresh food. The most unnatural condition introduced, so it seemed to the writer, was the fact that the pieces of cornstalks sometimes became slightly soured before they were replaced. In a few cases it seemed that natural decay, which sometimes sets in overnight in our climate, was the cause of the death of the larvæ, but other larvæ were able to withstand a condition which seemed actually identical in every respect. So it seems we are safe in concluding that the conditions were perhaps comparable with conditions in the field, and for the present, at least, we might say that no more larvæ die in the laboratory under the above conditions than would die in the field under natural conditions.

Therefore the following figures are presented for what they are worth. Of the 265 larvæ tested for this point, 138 passed through their various molts and were able to pupate; in other words, a mortality of slightly more than 45 per cent from egg to pupa.

In our regular breeding cages, where an attempt was made to secure every molt, 119 larvæ out of 276 died before they were able to pupate.

These were distributed as follows: 53 larvæ died before passing first molt, 18 larvæ before passing second molt, 14 larvæ before passing third molt, 14 larvæ before passing fourth molt, and 20 larvæ before passing fifth molt or pupating. This gives a total mortality from egg to pupa of slightly more than 43 per cent; figures in every way comparable to those above.

DESCRIPTION OF THE PUPA

Pupa stout, naked, soiled whitish in color, a typical rhynchophorus pupa with the following minor points (Figs. 48, 49, and 50).

Ventral view: rostrum stout, reaching between the first pair of tibia, with three pairs of prominent tuberculate hairs on the base; antennæ elbowed, almost equaling the front femora; eyes not prominent; legs sub-equal in length, the hind pair covered by the wings, each femora with a stout hair near its distal end, tarsi not distinctly jointed, wings with prominent longitudinal ridges; five stout tuberculate hairs on the eighth ventral segment of the abdomen.

Lateral view: head deflexed; prothorax depressed anteriorly, usually with two short tuberculate spines, one about middle of anterior half and the other about middle of posterior half; prothoracic spiracles large; wings prominent, curving ventrally between second and third pairs of legs, covering basal half of hind femora, with ten prominent longitudinal ridges; first six abdominal spiracles rather prominent, the others not evident, four long hairs on the dorsal part of the eighth abdominal segment.

Dorsal view: head nearly concealed by the prothorax; meso-thorax and meta-thorax distinct, the former terminating posteriorly in a prominent triangular lobe between the wings; the first to sixth abdominal segments nearly equal in size, with two groups of slender tuberculate marginal hairs either side of the median line, the hairs in either group about equidistant from each other, four in number; laterally there is a single tuberculate hair about mid-distant between the spiracle and the marginal group of tuberculate hairs; the seventh abdominal segment destitute of hairs save a single lateral pair; the eighth with the four pairs of hairs as described above.

SIZE OF PUPÆ

In all, twenty pupæ were measured, selected at random throughout the season. Two measurements were taken; the total length measured while the pupa was resting on a flat surface and the width across the mesothoracic legs measured from patella to patella. These measurements are given in Table XI below.

The extremes in length being 11.08 mm. and 15.74 mm., the average being 12.99 mm. The width varied from 5.08 mm. to 6.43 mm., the average being 5.69 mm.

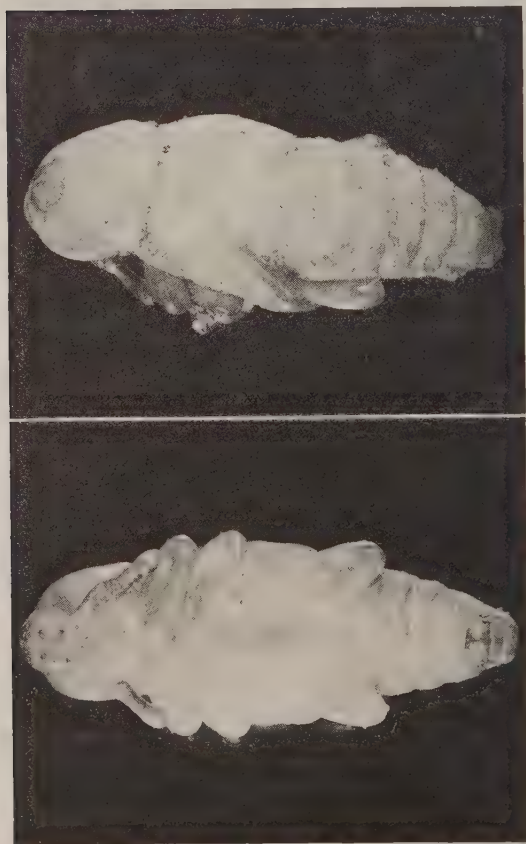


FIGURE 48. Young pupa, ventral view. X6.

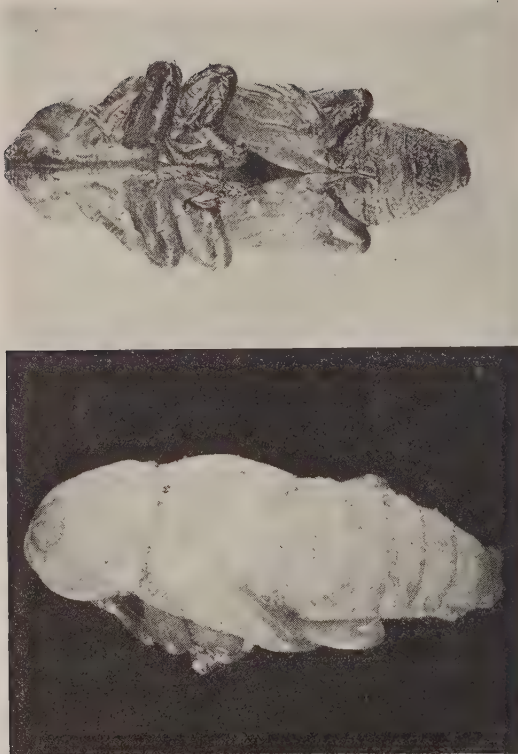


FIGURE 49. Dorsolateral view of young pupa. X6.



FIGURE 50. Old pupa, ventral view. X6.



FIGURE 51 Pupa in pupal cell, lateral view X6



FIGURE 52 Pupa in pupal cell, dorsal view X6

TABLE XI.
MEASUREMENTS OF 20 PUPÆ OF THE CORN BILL BUG.

Number	Total Length in mm.	Width Across Mesothoracic Legs in mm.
1	13.87	6.17
2	15.74	6.43
3	12.26	2.56
4	13.56	6.13
5	14.39	6.04
6	12.65	5.47
7	11.39	5.26
8	12.56	6.17
9	12.56	5.56
10	11.08	5.08
11	13.39	5.95
12	14.30	6.13
13	13.56	5.65
14	11.30	5.30
15	12.95	5.86
16	12.13	5.13
17	13.48	5.26
18	13.08	6.08
19	12.95	5.30
20	12.65	5.65

PUPAL CELLS

In our work in the insectary and laboratory the larvæ when they became full grown formed a compact oblong-ovoid cell in the stalk of corn, using partly masticated pieces of the cornstalk to plug the larval burrow and compacting the whole by interminable turnings and twistings as noted above (Figs. 51, 52, 53, and 54). In these cells the pupa fit loosely.

In the field some pupal cells are formed in the stalks of corn and some are formed in earthen cells in the soil just beneath the roots, usually about one inch deeper than the hole made when we pull a stalk up by the roots (Figs. 56 and 57). These cells made in the soil are smooth and compact internally, but are unlined for the most part. Occasionally one finds a pupal cell where the tap-root has been entirely eaten away; then the pupal cell may be lined with fragments of the well masticated tap-root. But so far as our observations go, the larvæ do not move material very far with which to make the lining of their pupal cells, but take whatever comes first to hand, be it either fragments of stalk or roots or particles of soil.

EFFECTS OF MOISTURE UPON THE PUPÆ

The pupæ seem to be little affected by moisture. They can be drowned by complete immersion in water, but anything much short of complete immersion seems to have little effect upon them. Neither does

the amount of moisture seem to have much effect upon the duration of the pupal stage. Pupæ kept in tight tin boxes with the air more than saturated with water emerged on the average in the same time as pupæ which were exposed to the dry air of an average room or those exposed to the average humidity out of doors in a screened insectary.



FIGURE 53. Pupal cells formed of corn fiber for protection of pupa; empty pupal cell on left was formed in the soil just beneath corn stalk in which the larva completed its growth. Pupal cell shown in corn stalk was in natural position at lower end of feeding cavity.

MORTALITY OF THE PUPA

Not as extensive figures have been kept on the mortality of the pupæ as upon the mortality of the larvæ. During 1915 147 pupæ were observed; from this number 110 adults were secured, giving a total mortality of slightly more than 18 per cent. Whether this is comparable to conditions as they exist in the field has not been determined. Observations made during the course of this project would lead one to believe, however, that this figure is somewhat high. The pupæ used in this experiment were not often disturbed, and frequently the stalks of corn became moldy or decay set in before they were observed again. Usually the mold or bacteria present infected the pupæ, causing their death in a majority of cases.

This condition must be wanting or very unusual in the field, for out of hundreds of pupæ observed in the field, both in cyperus and in corn, the writer has never seen a single decayed or moldy pupa. Hence it seems that we would be safe in concluding that a death rate of 18 per cent is abnormally high for pupæ.

DURATION OF THE PUPAL STAGE

In 1911 fifty-three adults were reared from pupæ whose larval stages had been followed. These all passed through the pupal stages in from eight to eleven days; the greater number maturing in nine days after they had pupated.

In 1915 one hundred and ten adults were reared from pupæ whose larval stages had been followed from the hatching of the egg. These matured in from four to twelve days; the greater number maturing in from seven to eight days.

From these figures it would seem safe to conclude that seven to nine days represent the normal length of the pupal stage; the time, perhaps, inclining somewhat toward the longer time, as is represented in Fig. 58.

As is mentioned elsewhere, variations in humidity seem to have very little effect upon the rapidity with which corn bill bugs pass through the pupal stage. The normal variations in temperature during the summer months seem to affect them only slightly, if at all, for the average time for pupæ reared in an out-of-doors insectary during July is practically the same as for pupæ reared in September.

The length of time required for larval development seems likewise to have no influence upon the time required for pupal development. In other words, the average time required for a bill bug with a total larval period of twenty to thirty days to pass through the pupal stages is so near the same as the average time required for bill bugs that have a total larval period of thirty to forty days or forty to fifty days that we seem safe in concluding that the length of the larval period has no influence whatever upon the length of the pupal period (Fig. 59).

TABLE XII.
DEVELOPMENT OF 53 PUPÆ, SEASON 1911.

Record Number	Larval Development— Number Days	Date of Pupating	Date of Emerging	Pupal Development— Number Days	Sex
1	48	July 22	July 31	9	Female
2	34	July 8	July 17	9	Female
3	34	July 8	July 16	8	Male
4	40	July 19	July 28	9	Female
5	35	July 14	July 22	8	Female
6	32	July 11	July 20	9	Male
7	29	July 9	July 18	9	Male
8	27	July 7	July 15	8	Female
9	26	July 6	July 14	8	Male
10	44	July 24	Aug. 3	9	Female
11	33	July 13	July 28	9	Female
12	36	July 16	July 24	8	Male
13	30	July 10	July 19	9	Female
14	30	July 10	July 19	9	Female
15	38	July 19	July 28	9	Male
16	35	July 19	July 28	9	Male
17	36	July 20	July 29	9	Female
18	33	July 17	July 26	9	Male
19	30	July 15	July 24	9	Female
20	26	July 12	July 21	9	Female
21	28	July 12	July 21	9	Male
22	32	July 18	July 26	8	Female
23	40	July 26	Aug. 5	10	Female
24	26	July 18	July 26	8	Female
25	47	Aug. 7	Aug. 15	8	Female
26	30	July 22	July 31	9	Female
27	42	Aug. 3	Aug. 12	9	Female
28	46	July 29	Aug. 7	9	Female
29	32	July 25	Aug. 4	10	Female
30	29	July 21	July 31	10	Female
31	33	July 25	Aug. 4	10	Female
32	30	July 22	July 31	9	Female
33	35	July 29	Aug. 7	9	Male
34	26	July 19	July 29	10	Female
35	30	July 24	Aug. 3	10	Female
36	53	Aug. 17	Aug. 26	9	Male
37	38	July 25	Aug. 3	9	Male
38	36	Aug. 1	Aug. 10	9	Male
39	28	July 26	Aug. 4	9	Male
40	27	July 25	Aug. 3	9	Male
41	37	Aug. 3	Aug. 12	9	Male
42	27	July 26	Aug. 4	9	Female
43	26	July 24	Aug. 3	10	Male
44	27	July 26	Aug. 4	9	Male
45	34	Aug. 2	Aug. 10	8	Female
46	29	July 27	Aug. 6	10	Female
47	30	July 29	Aug. 7	9	Female
48	34	Aug. 5	Aug. 14	9	Female
49	32	Aug. 6	Aug. 15	9	Female
50	26	Aug. 2	Aug. 11	9	Female
51	30	Aug. 7	Aug. 15	8	Female
52	36	Aug. 18	Aug. 27	9	Male
53	36	Sept. 12	Sept. 23	11	Female

TABLE XIII.
DEVELOPMENT OF 110 PUPÆ, SEASON OF 1915.

Record Number	Larval Development— Number Days	Date of Pupating	Date of Emerging	Pupal Development— Number Days	Sex
1	46	July 10	July 18	8	Female
2	30	July 5	July 13	8	Male
3	37	July 7	July 15	8	Male
4	38	July 13	July 19	6	Female
5	38	July 13	July 19	6	Male
6	34	July 11	July 18	7	Female
7	36	July 14	July 21	7	Male
8	30	July 9	July 17	8	Female
9	32	July 13	July 19	6	Female
10	37	July 18	July 27	9	Female
11	31	July 13	July 20	7	Female
12	37	July 19	July 26	7	Male
13	31	July 14	July 19	5	Female
14	22	July 6	July 13	7	Male
15	24	July 8	July 17	9	Male
16	29	July 14	July 24	10	Male
17	34	July 19	July 28	9	Female
18	32	July 17	July 28	11	Female
19	30	July 15	July 20	5	Male
20	26	July 11	July 17	6	Female
21	27	July 13	July 18	5	Male
22	33	July 19	July 26	7	Male
23	30	July 17	July 24	7	Male
24	29	July 17	July 24	7	Male
25	29	July 17	July 21	4	Male
26	32	July 20	July 28	8	Female
27	33	July 21	July 28	7	Male
28	26	July 14	July 21	7	Female
29	31	July 20	July 28	8	Female
30	35	July 24	July 31	7	Female
31	33	July 22	July 30	8	Male
32	32	July 21	July 29	8	Female
33	33	July 22	July 30	8	Female
34	26	July 15	July 22	7	Male
35	33	July 22	July 30	8	Female
36	37	July 27	Aug. 3	7	Female
37	31	July 21	July 29	8	Male
38	35	July 25	Aug. 2	8	Male
39	28	July 20	July 29	9	Male
40	42	Aug. 3	Aug. 7	4	Male
41	47	Aug. 8	Aug. 16	8	Male
42	32	July 24	Aug. 1	8	Female
43	37	July 30	Aug. 5	6	Female
44	45	Aug. 7	Aug. 15	8	Male
45	34	July 27	Aug. 3	7	Female
46	43	Aug. 7	Aug. 14	7	Male
47	35	July 31	Aug. 7	7	Male
48	36	Aug. 2	Aug. 10	8	Female
49	37	Aug. 3	Aug. 11	8	Female
50	27	July 24	Aug. 1	8	Male
51	38	Aug. 3	Aug. 8	5	Female
52	27	July 24	Aug. 1	8	Male
53	37	Aug. 3	Aug. 8	5	Female
54	25	July 22	Aug. 29	7	Male
55	38	Aug. 5	Aug. 13	8	Male

Record Number	Larval Development— Number Days	Date of Pupating	Date of Emerging	Pupal Development— Number Days	Sex
56	23	July 21	July 29	8	Male
57	34	Aug. 1	Aug. 8	7	Female
58	42	Aug. 10	Aug. 18	8	Male
59	27	July 26	Aug. 2	7	Female
60	34	Aug. 3	Aug. 10	7	Male
61	37	Aug. 6	Aug. 14	8	Female
62	40	Aug. 9	Aug. 16	7	Female
63	38	Aug. 7	Aug. 14	7	Male
64	34	Aug. 3	Aug. 10	7	Female
65	35	Aug. 5	Aug. 13	8	Female
66	44	Aug. 14	Aug. 27	8	Female
67	29	July 30	Aug. 5	6	Male
68	41	Aug. 12	Aug. 20	8	Female
69	31	Aug. 2	Aug. 9	7	Female
70	28	Aug. 2	Aug. 8	6	Male
71	32	Aug. 6	Aug. 13	7	Female
72	30	Aug. 4	Aug. 12	8	Male
73	26	July 31	Aug. 7	7	Female
74	24	July 30	Aug. 5	6	Male
75	35	Aug. 10	Aug. 18	8	Female
76	48	Aug. 14	Aug. 22	8	Female
77	36	Aug. 12	Aug. 20	8	Female
78	32	Aug. 8	Aug. 15	7	Male
79	30	Aug. 6	Aug. 13	7	Male
80	41	Aug. 18	Aug. 25	7	Male
81	30	Aug. 7	Aug. 14	7	Female
82	32	Aug. 9	Aug. 16	7	Female
83	31	Aug. 8	Aug. 15	7	Male
84	25	Aug. 2	Aug. 8	6	Male
85	30	Aug. 7	Aug. 14	7	Female
86	26	Aug. 6	Aug. 13	7	Male
87	29	Aug. 9	Aug. 17	8	Female
88	30	Aug. 10	Aug. 18	8	Female
89	27	Aug. 12	Aug. 20	8	Female
90	34	Aug. 19	Aug. 27	8	Female
91	28	Aug. 14	Aug. 21	7	Female
92	28	Aug. 14	Aug. 21	7	Female
93	25	Aug. 11	Aug. 18	7	Female
94	38	Aug. 25	Sept. 6	12	Female
95	27	Aug. 16	Aug. 25	9	Male
96	35	Aug. 24	Sept. 2	9	Female
97	35	Aug. 24	Sept. 2	9	Male
98	35	Aug. 24	Sept. 2	9	Female
99	30	Aug. 21	Aug. 30	9	Female
100	29	Aug. 20	Aug. 29	9	Female
101	31	Aug. 23	Sept. 2	10	Female
102	30	Aug. 21	Aug. 29	8	Female
103	23	Aug. 16	Aug. 25	9	Male
104	34	Aug. 29	Sept. 7	9	Female
105	31	Aug. 26	Sept. 6	11	Female
106	34	Aug. 29	Sept. 8	10	Female
107	28	Aug. 23	Sept. 1	9	Male
108	22	Aug. 18	Aug. 29	11	Male
109	30	Aug. 26	Sept. 6	11	Female
110	26	Aug. 22	Aug. 31	9	Female



FIGURE 54. Pupae and pupal cell formed of corn fiber; two small pupae on left dorsal and lateral views; on right live pupa in its pupal cell. X2

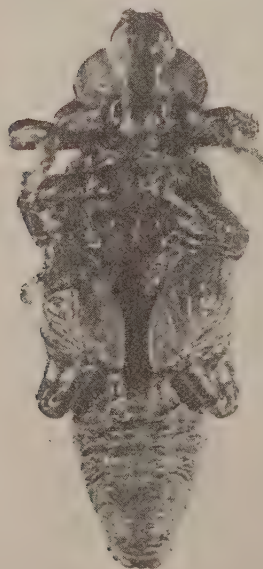
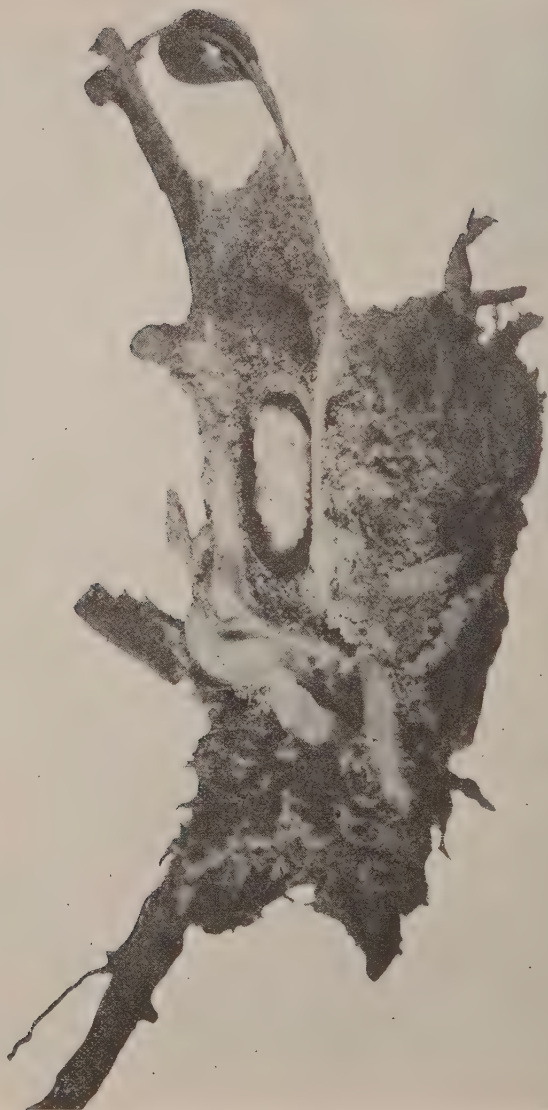


FIGURE 55. Adult emerging from pupa, only the prothoracic legs and the beak are free. X6.



FIGURE 56. Pupa in pupal cell in tap-root. X1.



FIGUR: 57. Pupa in pupal cell in ground among roots of corn stalk. X2.

TRANSFORMATION OF PUPA

The Molting of the Last Larval Skin

Usually about forty-eight hours before a larva is ready to transform to a pupa it ceases to feed, assumes a straight, rigid form (Fig. 29), and commences to turn over and over inside of the cell. This seems to compact the material with which the cell is lined and at the same time smooths the interior of the cell. This stage may be known as the prepupal stage, and larvæ usually assume this stage about forty-eight hours before they are ready to pupate. Cases have been observed, however, where the prepupal stage was assumed three days before pupation; in other cases, however, this stage is not assumed until the last day before pupation.

Just before pupation actually takes place the perfectly formed pupa may be distinguished through the transparent larval chitin. The larval chitin splits first along the epicranial and frontal sutures, and the prothorax is the first part of the pupa to emerge clearly from the cast skin, due to the fact that the head of the pupa is bent ventrally. Gradually the cast skin splits more and more posteriorly and is worked away from the body by the pupa turning and twisting its abdomen about (Fig. 31). The larval cast skin covering the legs and beak is the last to be freed from the pupa, this part of the cast skin frequently clinging to the pupa for several days. Usually the whole transformation from prepupa to pupa takes place in thirty minutes, sometimes, however, it takes longer than this. In one case observed the splitting of the larval cast skin commenced at 6 in the evening but the pupa did not have its abdomen free from the larval cast skin until the next day between 9 and 10 in the morning. Such occurrences must be rare, however, for the only other case observed, where it required the pupa longer than an hour or two to free itself from the larval skin, the pupa died before it was able to free itself, indicating that it was not normal.

The pupa is at first a pure translucent white, but in the course of a few hours it turns a pale straw yellow and retains this color until the developing adult's dark colored body can be seen through the translucent pupal skin (Figs. 48-50). This color can usually be noticed a day or two before the adult is ready to emerge.

HABITS OF THE PUPA

The pupa is naturally confined to its pupal cell. Therefore it has no habits that are especially interesting. When the pupa is disturbed it bends its abdomen first dorsally, then ventrally, and is thus able to rotate its body. It does not usually keep this process up very long before it relaxes. Usually the period of relaxation is approximately as long as the period of action which has just preceded. In most cases it takes a very violent disturbance to make the pupa become active before the period of relaxation has been of approximately the same

duration as the period of activity. These alternate periods of activity and relaxation seem to follow each other in fairly regular succession over long periods of time. I do not mean to imply by the above statements that there is any accurate mechanism which regulates the periods of relaxation with those of activity, but repeated observations showed that it took a much more violent stimulus to cause activity in a pupa that had recently relaxed than it did in a pupa that had been relaxed for some time. And apparently the longer the period of relaxation, the smaller the stimulus required to produce activity.

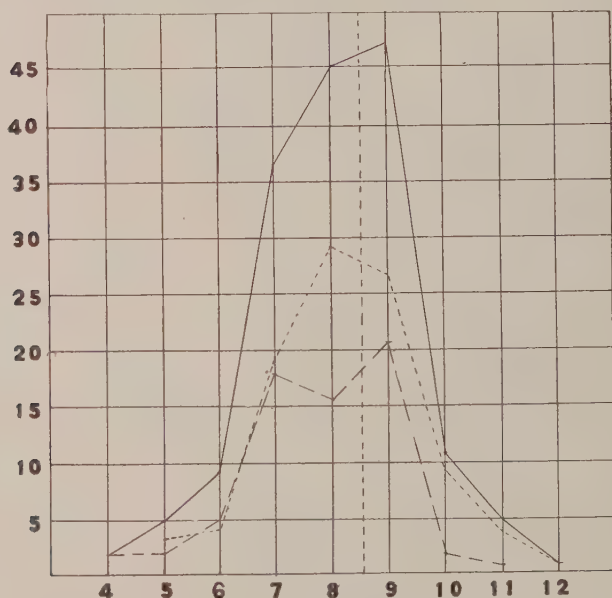


FIGURE 58. Curve to show duration of pupal stage. Dotted line (....) females. Dashed line (— — —) males. Solid line (——) totals.

DESCRIPTION OF THE ADULT

The following description of the adult is summarized from Blatchley and Leng (1916), our most recent authorities on this group:

Tibiæ all broadly rounded at outer apical angle. Third joint of hind tarsi feebly dilated. Third joint of other tarsi not dilated, entirely glabrous beneath. Elytral intervals all flat, no single one of them in part or wholly distinctly elevated above the others. Beak curved, slender. Front tibiæ straight. Thorax with distinct smooth spaces. Median thoracic smooth area dilated at middle. Surface densely coated.

Oval robust. Black, densely clothed with a brownish or olivaceous clayey coating; antennæ and tarsi reddish-brown. Beak two-thirds the

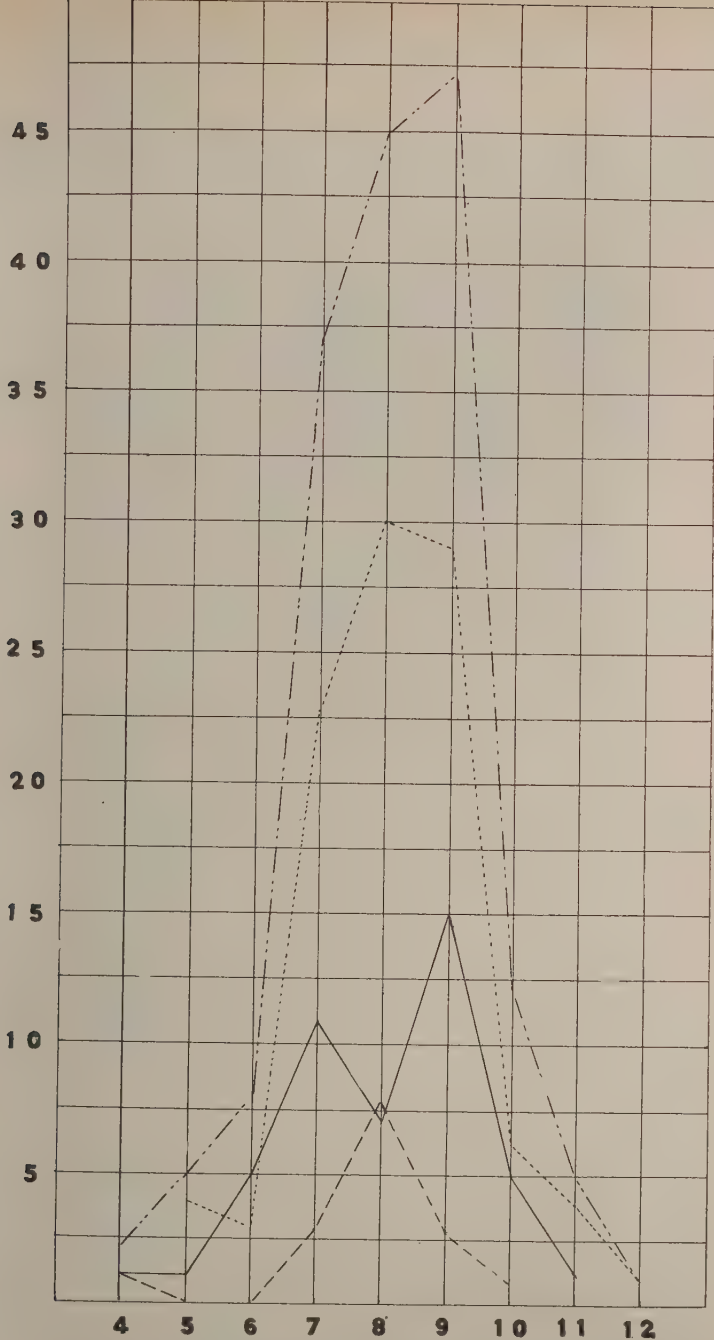


FIGURE 59. Curve to show the relation between duration of larval stage and duration of pupal stage. Solid line (—), pupæ whose larvæ required from twenty to thirty days to complete their development; dotted line (.....) pupæ whose larvæ required from thirty to forty days to complete their development; dashed line (---) pupæ whose larvæ required from forty to fifty days to complete their development; dashed and dotted line (-.-.-.-) totals for all pupæ observed.

length of thorax, compressed and sparsely punctate except near base, where it is swollen, coarsely punctate, and shallowly grooved above. Thorax slightly longer than wide, sides parallel from base for three-fourths their length, then strongly rounded to the constricted apex; disc very coarsely and irregularly punctate, the median vitta usually broadly dilated at middle, its apical portion very narrow; lateral vittae broad at base and with a short oblique branch, their front portion often replaced by coarse punctures. Elytra oval, their surface uneven, sides gradually narrowed from humeri to apex; striae fine, coarsely and distinctly punctate; intervals flat, their punctures hidden, and third sometimes feebly base. Humeral umbone and sub-apical callus somewhat prominent, often shining.

DURATION OF LIFE OF THE ADULT

The adult beetles found in any corn-field during the spring and early summer must, for the most part, be adults that matured the previous June, July, August, September, and October, as the adults live over the winter. (See discussion of hibernation of adults.) Laboratory experiments seem to indicate that occasionally, at least, adults might be able to live over two winters. We have never been able to keep adults through two winters, due, perhaps, to the fact that conditions are not normal; but we have been able to keep them through one winter and through the next winter until the first of March.

These beetles were collected June 20, 1910, and represented the 1909 generation, and must have matured the previous June, July, August, September, or October. They were, therefore, from seventeen to twenty-one months old when they died. These beetles might have lived longer than March 1, 1911, if they had not been disturbed during January and February to see whether they were alive. However, a miscellaneous lot of beetles hatched during the summer of 1912 and used for egg laying records during 1913 all died before the spring of 1914, in spite of the fact that they were not disturbed. A similar fate awaited those adults reared during the summer of 1913. At the present writing, November 26, 1915, five out of the 1914 generation are still alive. In June, 1913, about 500 adults were marked in various ways to see whether any of these adults which undoubtedly represented those emerging during the summer of 1912 would be able to pass through the winter. None of these marked beetles were recovered during 1914. But in spite of this fact the writer believes that occasionally a beetle might be able to live through the winter. At least they are able to go into hibernation, and it seems only reasonable to suppose that occasionally they are able to emerge from hibernation, although at the present time we have no evidence to support this conclusion. These might represent the adults which lay only a few eggs during the summer (see egg-laying records above). At least, we have not been able to assign any other cause to the failure of certain adults to lay

anything that even approximates the average number of eggs laid by a majority of the females. On the other hand, the adult females that lay only a few eggs might be females that matured early the previous summer and laid a portion of their eggs during the previous season.



FIGURE 60. Adult dorsal view. X8.

PROPORTION OF SEXES

Of the 163 individuals that have been reared from egg to adult, 95 individuals or slightly more than 58 per cent were females, while 68 or a little less than 42 per cent were males.

In the field the proportion of sexes seems to be more nearly equal. As a usual thing, active females are attended by males, and inactive beetles under stones, sticks, or clods of dirt are usually equally males and females. In July, 1912, this point was made a special point for investigation, and in all 627 individuals were counted and so marked

as to prevent their being recounted. It is believed that this represents practically all of the bill bugs present on a plat of one-third acre. Of 627 individuals, 329 or slightly more than 52 per cent were females; while 298 or slightly less than 48 per cent were males. In addition to this, many other observations and the counting of smaller numbers of bill bugs would indicate that the proportion of sexes in the field was approximately equal. The table below will indicate the approximate numbers of bill bugs and their distribution as determined from counting all the bill bugs that could be found on a plat about one-eighth of an acre in extent as counted June 10, 1915, between 10 a. m. and 3 p. m. In this case over 60 per cent were males and less than 40 per cent were females. And while it is possible that some bill bugs may have been missed, an effort was made to secure all of the bill bugs present, and certainly the vast majority of the bill bugs present on that date were recovered and counted. This incident is merely cited as one of the incidents that force us to the conclusion that the proportion of sexes must be nearly equal under ordinary conditions, in spite of the fact that in the total numbers counted from all sources there are 110 females to every 100 males.

TABLE XIV.

SHOWING THE DISTRIBUTION OF ADULT BILL BUGS ON JUNE 10, 1915. PLOT A—ONE-EIGHTH OF AN ACRE.

	Females	Males
Feeding.....	2	2
Egg laying.....	1	0
Actively crawling about.....	0	1
Under clods, sticks, etc.....	24	39
Totals.....	27	42
Per cent.....	40	60

APPEARANCE OF THE ADULTS IN THE SPRING

In the eastern part of the State the adults appear in the corn-fields as early as mid-April. Their numbers increasing gradually, as the weather grows warmer, so that usually by the first of June all the overwintering beetles seemed to have emerged from hibernation, and usually towards the end of June their numbers seem to be increased by newly transformed adults which may be readily distinguished at the time of their emergence by their velvety brown color. The numbers of adults increase gradually during July and the first half of August. The bill bugs usually completely disappear in fields of corn planted in April and May by the latter part of August. These bugs seem to locate in later planted corn if any be available, but just where they go if corn is not available has never been definitely determined. Perhaps they

feed upon some of the wild food plants, but close observation fails to show any especial increase in their numbers in such situations. Neither can any be found in the usual hibernation situations save young beetles which have evidently not yet emerged from their pupal cells.

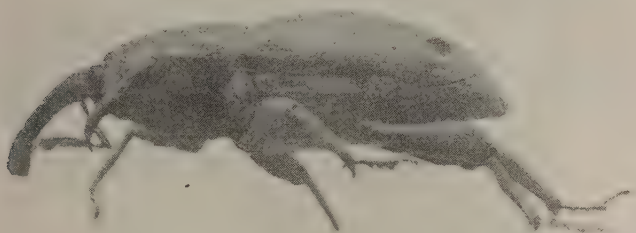


FIGURE 61. Adult lateral view. X6.

DIURNAL ACTIVITY

The diurnal activity of corn bill bugs in the field was made a special point for investigation during the summer of 1912, and since that time many additional observations have been made which support the conclusions drawn at that time. In making these observations, 627 adults, 329 of which were females and 298 were males, were marked in various ways and studied throughout the month of July and part of August. These adults, it is believed, represented all of the individuals present on a plat of about one-third of an acre in extent. Observations were made at various times for every hour of the day and night. From these observations we have concluded that there are two main periods of activity for the corn bill bug, the activities for the most part consisting of feeding and egg laying for the female and feeding and mating for the males. For a fuller discussion of these activities, see habits of adults below. Two main daily periods of activity are followed by two periods of inactivity, when the bill bugs crawl away under any shelter that may present itself, such as clods, partially buried sticks or pieces of cornstalks and stones. The activities vary somewhat from month to month and from day to day. But the activities on a cool, cloudy day late in the season approximate the activities on a warm, bright day early in the season. I have attempted to reduce all of these observations to the form of a curve (Fig. 62).

In order that all of the observations made during the summer of 1912 and during the following summers might be correlated, the ob-

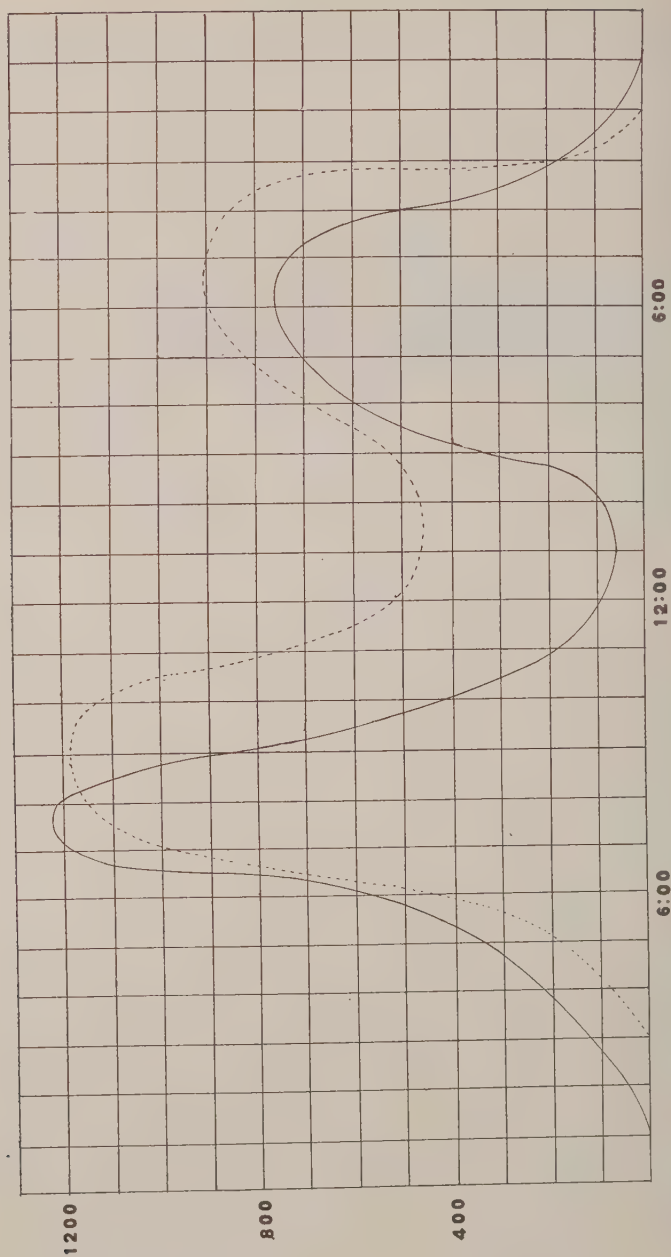


FIGURE 62. Curve to show diurnal activity based on counts as made in the field. Solid line (—) to represent activity from mid to late season. Dashed line (---) to represent activity early in the season. On the basis of hundreds active per acre.

servations on the diurnal activities for bill bugs have been reduced to a curve representing the numbers of bill bugs active per acre. This curve does not take into consideration the number of bill bugs that were not active, as it was impossible to be absolutely sure whether you had actually secured all of the inactive bugs lying under clods and in similar situations. On the other hand, it was usually a comparatively simple matter to determine the number of bugs which were feeding, laying eggs, or otherwise engaged in any of the daily activities of adult corn bill bugs.

On the plat where most of the observations were made during the summer of 1912, 627 adult corn bill bugs of both sexes were found. This plat represented about one-third of an acre. Thus we have bill bugs occurring at the rate of more than 1,800 per acre. Yet in spite of this fact, the average rate per acre at the period of greatest activity, about 8 a. m., was usually not more than 1,200 per acre. Some other observations made in 1913 confirmed this general conclusion, that is, that even at the period of greatest activity only about two-thirds of the bill bugs in a given area would be actively engaged in feeding or egg laying.

From an inspection of Fig. 62 it will be observed that on the average bright day in mid-season the two main periods of activity are from 6 to 9 a. m. and from 4 to 8 p. m. The main periods of inactivity are from 10 a. m. to 3 p. m. and again from 10 p. m. to 3 a. m. Ordinarily on bright days no bill bugs will be found active from 11 p. m. to after 2 a. m. The first bill bugs become active between 2 and 3 a. m., these being joined by others between 3 and 4 a. m. So that on the average there are about 200 active bill bugs per acre by 4 a. m. Usually by 5 a. m. another 100 per acre have joined those already at work; by 6 a. m. the number of active bill bugs per acre has usually increased to 600, and by 7 o'clock this has usually doubled again; so that there are on the average about 1,200 bill bugs per acre actively engaged in feeding and egg laying. By this time some of the earlier ones to become active have begun to seek shelter, but usually there are enough more becoming active, so that up to 8 o'clock the numbers are about constant. Very few new ones join the ranks after 8 o'clock, so that the numbers drop off rather rapidly, and late in the season, during late July and early August, on clear days when the sun is very hot in the corn-fields practically all of the bill bugs will be under cover by 11 a. m., where practically all will remain until about 2 p. m. In mid-season, mid-June to mid-July, the later arrivals in the morning will linger through the warmer part of the day, so that it is not unusual to find bill bugs at the rate of 200 to 300 per acre at this time of the day.

Still earlier in the season, as from mid-May to mid-June, and on cloudy days later in the season, the bill bugs do not become very active until about 6 o'clock in the morning, but by this time there are usually

at the rate of 500 bill bugs per acre actively at work in the field. This number increases to nearly 1,200 per acre by 8 o'clock; this number remaining practically constant until 10 o'clock, when the number actively at work usually falls off rather rapidly to about 500 per acre at 12 o'clock. This number remains practically constant until about 3 o'clock, when the numbers commence to increase gradually up to from 900 to 1,000 by 5 o'clock. This number remains practically constant until 7 o'clock, when the number decreases very rapidly, so that by 9 o'clock practically every bill bug in the field has ceased his activities for the day, and if the weather remains cloudy these activities are not resumed until the following morning between 3 and 4, when a few of the earliest to cease their activities then again become active for the new day.

HABITS OF THE ADULTS

The egg-laying habits of adults are touched upon in another connection (see methods of oviposition below) and the general daily activities of adult bill bugs have been discussed under the heading of diurnal activities. However, the general feeding, mating, and other habits have not been discussed.

In discussing the habits of bill bugs one is almost forced to use terms which have long been used to denote conscious human actions. The writer has no intention of implying that either the stimulus or the reaction is the same as it would be in human beings, to produce the results described. He has merely used these terms because they happen to give the clearest picture of the reactions of bill bugs to certain complexes of stimuli.

The adults feed at or near the level of the ground, tearing away the outer leaves of the plant so as to be able to get at the tender growing leaves or bud of the plant. In feeding, the bill bug always assumes a position with head downward. When the plant is young the bill bug may feed at a distance of an inch or two above the surface of the soil, but usually they have the head and thorax below the surface and not infrequently practically the whole body will be below the surface. Occasionally the adults are so completely buried that their presence is not suspected until the plant is pulled up, when the adult will be found clinging to the portion of the stem below ground. Usually, however, a portion of the pygidium is left exposed, so that close observation will reveal the presence of the adult. This, however, requires very close inspection, for, as explained above, the color of the bill bug very closely approximates the soil in which it is living, due to the fact that small particles of the soil adhere to the body.

The bill bug is not easy to dislodge from the corn plant while it is feeding. When disturbed it clings to the stalk of corn by means of the tibial spines, so that usually part of the stalk of corn is torn away before the bill bug is removed.

In its movements the bill bug is very slow and deliberate, evidently depending upon its color and slow gait for protection. At times the adult moves rather rapidly, but this gait is not long continued, and usually after each period of rapid movement it will remain perfectly motionless for a period usually equaling if not exceeding the period of rapid movements. This jerky gait always impresses one with the thought that the bill bug fully expects every movement it makes to betray it to its enemies. Their total movements thus become so slow as to exhaust the patience of any human being who is observing them in the hope that he will get a composite picture of their activities. The same slowness of gait applies to all of their activities, be it mating, egg laying, feeding, or what not. All of the movements of the bill bug seem to be entirely aimless and without any definite purpose, or such is my conclusion, after watching them for the past several seasons both in the field and in the insectary. In the field bill bugs on coming from their retreats under clods or sticks will proceed in a jerky manner often for a distance of many feet, often passing in their wanderings within a fraction of an inch of stalks of corn, to bring up eventually at a stalk that is, so far as one can observe, not better in any way than stalks that have just been passed. Frequently they will take such journeys of exploration, sometimes wandering across a plat of corn thirty or more feet in direct line from the starting point, only to turn in an aimless fashion, partly retracing their steps and winding up at a stalk of corn within a few inches of their retreat, where they will commence to feed and continue to feed long after their companions have sought their shelters for their noontime siestas. These aimless wanderings seem decidedly more common during the morning hours than they are during the evening hours. It is for all the world as if these fellows had after a night's rest arisen refreshed in body and started out on a journey of adventure to the far recesses of their domain. At first it was supposed that these wanderings were for the purpose of seeking mates, but, so far as our observations go, bill bugs possessed with this wander-lust do not seek mates. In fact, in the majority of cases, as discussed below, coupling seems ordinarily to take place before the bill bugs emerge from their retreats.

The mating habits of the bill bugs are rather interesting. The males for the most part seek the females while they are still in their retreats. Coupling takes place usually at this time. Actual copulation does not usually take place until the bill bugs have come out from their retreats, the female carrying the male about until she has found a suitable stalk in which to oviposit. Then, while the females are making the egg cavity, copulation usually takes place. Copulation is usually completed long before the egg cavity is completed; the male, however, may continue to cling to the female for a considerable time after copulation, not infrequently clinging until oviposition is completed and sometimes clinging until the female starts another egg cavity. Sooner or later,

however, the male releases his hold on the female, usually crawling away to another stalk of corn, where he commences to feed, or, if the day be well advanced, he may return directly to a retreat. This results in very promiscuous matings, for in no case have the same individuals been found mated on consecutive days.

The time spent by individuals in feeding on a given plant varies greatly. Usually bill bugs after becoming established on a plant will remain as long as an hour, frequently for several hours. Records have been made of bill bugs feeding on the same plant for at least twelve hours, but such prolonged periods are rather unusual. In all such cases the bill bugs have been protected from the hot rays of the sun by overhanging corn leaves or they have been protected by being in a group of cornstalks.

In approaching a stalk for feeding purposes, the bill bug seems to locate it merely by accident, often passing within a fraction of an inch of a stalk that is apparently as good as the one finally selected. So far as observed, a stalk had to be directly in the path of the bill bug before it was selected. Frequently observations were made which would lead one to believe that if the bill bug could not escape it would proceed to feed on a stalk of corn that directly blocked its path. No cases have been observed of a bill bug emerging from its retreat and going directly to any stalk of corn; and in very few cases was the stalk of corn nearest the retreat selected, and then only after aimless wanderings, which usually caused the bill bug to cover many times the distance required. When an adult finds its path directly blocked by a stalk of corn it pauses for a longer or shorter period of time. Eventually it crawls up the stalk for a short distance, usually from one and a half to two times the length of its body, then turns deliberately around with the center of its body as a pivot until its body is parallel with the long axis of the cornstalk, with head downward. Usually it is then half the length of its body above the surface of the ground. It then crawls down the stalk until it reaches the surface of the ground, when it may insert its snout into the stalk or it may bury itself partially or completely below the surface of the soil. In making the egg-laying punctures the jaws usually tear away portions of the outside leaves, but in making feeding punctures the bugs seem for the most part to devour the substance of the stalk as the snout is inserted deeper into the stalk.

OVIPOSITION

Age of Adults At Beginning

In the insectary during the summer of 1915 all the female beetles commenced to lay eggs within two weeks of the time of emergence from the pupal cells, if they were provided with suitable food. Inasmuch as the beetles usually linger in the pupal cells from five to seven days after they have transformed to adults, we are justified in saying that adult

females commence laying from two to three weeks after they have transformed. This would mean, then, that the first adults that emerge in the early summer would commence to lay eggs that season and continue right through with their parents; whereas the beetles emerging late in the season would not find suitable corn in which to oviposit and would seek hibernating quarters and not commence egg laying until the following season. This, perhaps, accounts for the great variation in the numbers of eggs laid by individual females. (See egg-laying records above.)

EXAMINATION OF PLANT BEFORE BEGINNING OVIPOSITION

So far as our observations go, the adult female makes no preliminary examination of the plant in which she is going to oviposit. Instead, as discussed above under "Habits of the Adults," she simply seems to take any plant that offers. Neither is there any attempt to avoid plants already containing eggs. In one case, early in the season, a small plant was examined which contained five eggs, yet there were within a radius of six inches not less than four other plants that contained no eggs and many others in the same field near by which contained no eggs or only very few eggs.

The females which are making egg punctures may be readily distinguished in our experience from females that are simply feeding by the following characteristic actions. Feeding adult bill bugs either male or female take their position head downward on the stalk at or below the level of the ground, usually higher on the plant than egg-laying beetles. The body of the feeding beetles, so far as we have observed, remains motionless, the tarsi only being moved and the beak seeming to sink without effort into the stalk. On the other hand, adults preparing egg cavities seem to take a position lower on the stalk than feeding beetles, and, in addition, their bodies are pulled back and pushed forward as the beak is inserted; thus instead of a small round puncture a long oval puncture results, the beak acting somewhat as a wedge to separate the stalk as it is inserted deeper and deeper. While making the egg puncture the adults have their bodies parallel with the long axis of the stems of the plant, with head downward (Fig. 5), but when the egg cavity is finished they turn slowly about with the center of the body as a pivot and locate the egg cavity with the tip of the abdomen (Fig. 6). The tip of the abdomen is then slowly inserted into the cavity, the beetle retaining its hold upon the plant largely by means of the metathoracic and mesothoracic legs. Not infrequently the prothoracic legs are entirely withdrawn from the stalk. Oviposition completed, the beetles simply crawl away, sometimes going to shelters under clods or elsewhere, sometimes wandering about until they locate another stalk upon which they may feed or oviposit.

PLACING THE EGG

So far as our observations go the eggs are laid below the surface of the ground either in the stem of the plant or loosely among the roots. In young plants the eggs are simply placed in cavities eaten into the stem, but in older plants the eggs are carefully inserted in small pockets formed in the heavier outer leaves.

Only a few individuals have been observed to lay more than a single egg per day, but in all individuals observed laying more than one egg per day the first egg laid was deposited more carefully than later eggs. From this we have concluded that females that lay eggs loosely in the ground have deposited more than one egg for that day.

TIME REQUIRED FOR EACH INDIVIDUAL ACT OF OVIPOSITION

No hard and fast rule can be given about the length of time required in each individual act of oviposition. In general, the act may be divided into the following steps: (*a*) locating the plant, (*b*) turning head downward, (*c*) making the egg cavity, (*d*) turning with head up the plant and inserting the ovipositor, (*e*) ovipositing, (*f*) seeking shelter or another plant. Any one of these steps varies greatly with not only different beetles on different days, but with the same beetle at different times of the day and on different days. Any one of the steps may be hastened through in a few minutes or it may be prolonged for an hour or two. Sometimes one process is hastened forward with the greatest dispatch—perhaps, till it is completed; perhaps, till it is only partly completed; to be followed by a period when the beetle evidently does no work at all. If the beetle is disturbed in any way while engaged in any of the processes of ovipositing, it remains perfectly quiet for a longer or shorter period, but in no case observed did the bill bug leave the process of oviposition incomplected unless it was violently removed from the plant on which it was ovipositing.

Many beetles have been timed at all hours of the day, and, as a general rule, beetles are slower to complete the act of oviposition in the morning than they are in the evening, and slower in the evening than they are during the middle of the day. The following example of a bill bug observed almost constantly from about 6:50 a. m. until 11:45 a. m., during which time she laid two eggs, will be fairly illustrative of the time involved in the various steps of the whole process: An adult female, attended by a male, was first noted near a clod, under which there were two other females and a male, about 6:50; wandered aimlessly about until 7:05, when she approached a plant: end of step *a*. She stood perfectly still at the base of the plant until 7:18, when she started to crawl up the plant, turning around, head downward, this step (*b*) being completed a few seconds before 7:20. Worked on the egg cavity from 7:20 to about 8:05; last observed at 8:00 o'clock, not

again observed until 8:06, when she had withdrawn her beak and had turned her body so that its long axis was at about an angle of 10 degrees to the long axis of the plant. At 8:09 she had completely turned around, so that her abdomen was in the egg cavity, where it remained until 8:40. When the abdomen was withdrawn the male dropped off the back of the female without having copulated, and, after rolling away from the cornstalk a distance of three or four inches, crawled away to a stalk in the next row of corn and commenced feeding. The female remained with head up the stalk until about 8:50, when she started away in the opposite direction, proceeding in the usual manner of adult bill bugs by moving rather rapidly for a few inches, then remaining motionless for a longer or shorter period of time. She arrived finally at a stalk of corn in the next row, a distance of less than five feet, at about 10 o'clock; she then remained motionless at the base of the stalk for about 35 minutes, finally turning head downward hastily at 10:35 and commenced an egg-laying puncture. This cavity was completed by 11:15, when she turned around hastily, taking a little less than a minute to insert the tip of her abdomen in the cavity, from which it was withdrawn at 11:29; within another minute she had crawled away from the stalk a distance of three inches, where she remained in the shade cast by a weed until 11:45, where further observations were abandoned for the time. At shortly after 12 o'clock the same female was found under a clod within about five inches of the place where our observations had been abandoned.

EGG AND FEEDING PUNCTURES

If there is a characteristic difference in the method of making egg cavities and feeding punctures, as all our observations would lead us to believe, then we have a ready explanation of the reason that we have two kinds of punctures in the leaves of corn plants that have been injured by the bill bugs, one being circular in outline and the other oblong (Fig. 7). We believe from observations that have been made on young, rapidly growing plants where beetles were permitted to feed only, and in other cases where they were observed to oviposit, that the circular holes represent feeding punctures and the oblong holes represent egg punctures. At one time it was thought that this would enable one to readily determine the number of eggs laid in a field, and then, by carefully counting the number of females, to be able to calculate the average number of eggs laid by females in the field; but this was abandoned when it was discovered that eggs were frequently laid loosely in the ground.

EFFECTS OF THE ADULTS ON CORN

The adults do a great deal of damage to young corn by inserting their beaks into the stem, usually below ground, and eating out the tender forming leaves (Figs. 10 and 63). This soon makes itself apparent by



FIGURE 63. Corn stalk showing characteristic injury by adults.

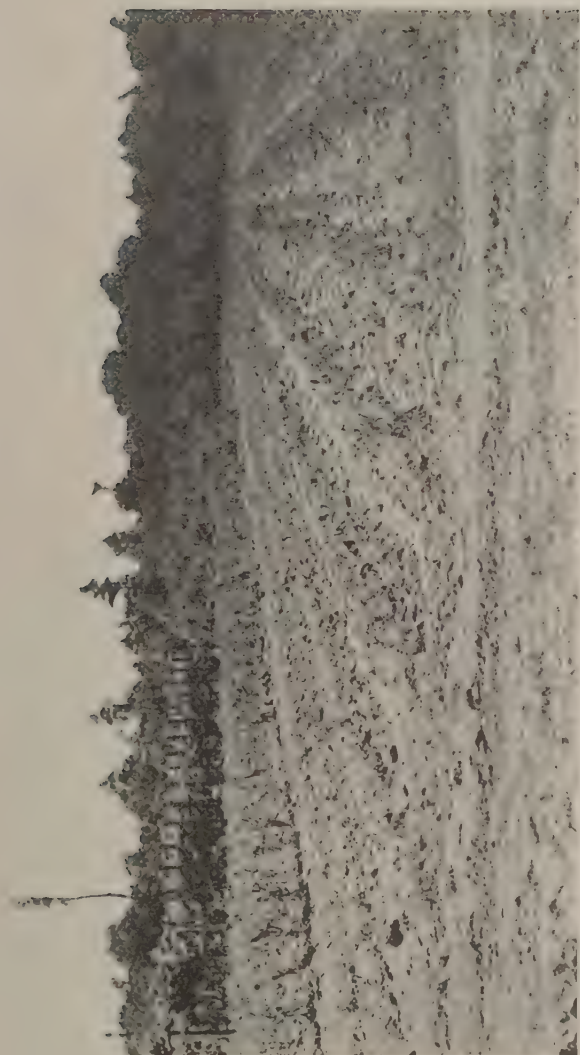


FIGURE 64. Experimental plot showing corn on the left too old to be much injured by adults.
Corn on the right being badly injured by adults.

rows of round or oblong holes running across the leaves. Frequently these rows of holes are found in the so-called seed leaf, indicating that the adults often attack corn as soon as it appears above ground. When young plants are attacked in this manner they never recover, but simply die. It is hard to arrive at a satisfactory estimate of the percentage of plants that are injured in this way, for in all of our experimental plats planted to test this phase of the problem we have had to deal with bad outbreaks of the Southern Corn Root-Worm, and while the methods of attack of these two insects are entirely different, yet frequently the same plants are attacked by both insects and under such conditions it is impossible to say which insect was responsible for the death of the plant.

After the plants have grown to some extent they are seldom killed outright by the adult corn bill bugs (Fig. 64). Their growth, however, is much stunted if the adults attack it frequently; but the adults do not seem to injure corn after it has started to grow to nearly the same extent that the larvæ do.

HIBERNATION

The adult is the only stage that has been found during the hibernation period. Hibernating adults have been found in three situations: among the roots of cyperus grass, in the larval burrows in stalks of corn, and in the pupal cells in the ground among the corn roots. Many hibernating bill bugs have been found in the field during the past three winters, and of the number found fully 90 per cent have been in the pupal cells in the earth underneath the corn stubbles. A few beetles have been found among the roots of clumps of cyperus grass at Raleigh and a few have been found in cornstalks at Willard. Those that occur in pupal cells in the ground seem for the most part to be late maturing beetles, and are more common in late corn, and especially in late corn that has been retarded in its growth, as corn growing under trees and in poor soil and other like situations.

The adults in the pupal cells in the ground are apt to occur anywhere among the roots, but they seem to be especially abundant directly beneath the tap-root. The former, perhaps, represent larvæ that have developed among the roots, while the latter undoubtedly represent larvæ that have developed in the stalk; for in practically every case where there are larval burrows in the stalks of late corn the adults will be found in pupal cells near the tap-root. On the other hand, farther away from the tap-root there are usually no evidences of larval burrows in the stalk. Most of the pupal cells in the ground are situated rather deep, usually an inch or two below the bottom of the cavity caused by pulling up the stubbles. In fact, it is very rarely that one finds a hibernating beetle by pulling up the corn stubbles, unless the beetle happens to be in the larval burrow in the cornstalk. In February, 1913, I pulled up over three hundred corn stubbles in a corn-

field where the corn bill bug damage had been very serious during the summer of 1912, and did not find a single corn bill bug until I took a spade and spaded the stubble out of the ground, taking care to get about three inches below the level where the roots would ordinarily break if the stubble had been pulled out directly. Then by carefully splitting the stalk lengthwise and dividing the soil below the tap-root, a bill bug could be found under practically every stalk that showed indications of a larval burrow. This occurred in about 60 per cent of the stalks in the same part of the field and in adjacent rows to those where we had pulled up over three hundred stalks and had not found a single adult. Occasionally one would find the lump of soil sometimes at a distance of five or six inches from the tap root. Perhaps more beetles occurred in such situations than we actually observed, for in the winter, when bill bugs are inactive, they are exceedingly difficult to distinguish from lumps of earth. When one was found in such situations it was usually due to the fact that the lump of earth adhering to the roots happened to break across the pupal cell, which would usually be conspicuous because it was a cavity with a smooth surface. Discovery of the pupal cell usually led to the discovery of the beetle; sometimes it was found projecting from the other half of the cell, but more often it was found among other little lumps of earth, from which it could usually only be distinguished by individual examination.

Thus it seems safe to conclude that the beetle stage is the only one that ordinarily passes the winter, for many adults have been discovered in hibernation and no other stages have been found. The only apparent exception to this statement is the record of a single pupa found by Mr. Hyslop, as recorded below; but, as explained elsewhere, the larvæ that develop from the last eggs laid in corn undoubtedly do not reach maturity before early November; hence this record would have to be excluded as a hibernating individual. Of the individuals that have been found in hibernating quarters, about 90 per cent were in pupal cells in the ground below the tap-root and about 2 per cent in the larval burrows in the stalks, and a little more than 7 per cent were in pupal cells among the roots.

The peculiar situation of the pupal cells perhaps accounts for the fact that others have had difficulty in locating hibernating bill bugs, as Mr. Smith's record will show.

"The bill bugs hibernate ordinarily in the beetle stage. This statement is made without reservation and is based on many field observations during the winter of 1909-1910, when careful search on several occasions failed to reveal any eggs, larvæ, or pupæ in the field where bill bugs were known to have bred during the previous falls. It has proved to be extremely difficult to find any bill bugs in their winter quarters, but the total absence of larvæ and pupæ in the breeding places proves that the winter is not passed in either of those stages.

"Only one record has been secured of actually finding the beetles in a place where they presumably pass the winter. On November 4 and 5, 1911, in company with Mr. J. A. Hyslop of the National Bureau of Entomology, adult bill bugs were found in corn stubble in a field on Harvey's Neck in Perquimans County. The trip to this field was made for the express purpose of trying to find the beetles, for it was assumed if any were found on that date that they would be in hibernation for the winter. After considerable search we located a dead beetle in a cornstalk. This beetle was at a point in the stalk about even with the surface of the ground. Soon afterwards we found another dead beetle in a similar location. On the second day three live beetles were found in cornstalks in a field where serious bill bug damage had occurred during the summer. Apparently these beetles had matured late and had not attempted to escape. We consider this to be proof of the hibernation actually occurring in the cornstalks. The beetles were in the stalk near the roots where the larva had fed and transformed.

"During these two days when beetles were found in cornstalks, we also searched for the beetles and the immature stages, in cyperus plants, but without success. In fact, there were only a few cyperus plants found in which *Sphenophorus* larvæ had lived. The writer believes, however, that the bill bugs had bred in cyperus in these fields in plants that had died down and become invisible.

"Hibernation must also occur in the soil, or under the protection of some material in the fields, as well as in cornstalks. The breeding of beetles during the past summer, when every reared specimen emerged and fed nearly every day thereafter until the middle of November, shows that it is the natural thing for the beetles to come out and feed after maturity. If this is true, the majority of the bill bugs are not hibernating in cornstalks unless they crawl into the stalk when cold weather commences. That this actually occurs is extremely doubtful. The beetles found in the cornstalks had certainly never emerged, and no beetles were found under conditions to indicate that they had crawled into the stalk.

"On November, 5, 1911, Mr. Hyslop found one healthy live pupa in a cornstalk. This indicates a possibility of the pupæ living in that situation all winter. The rearing records, however, do not indicate that pupæ are liable to live all winter. This point needs further investigation, but in view of present knowledge we may consider that only the mature beetles normally live during the winter.

"The writer has searched for the beetles in winter quarters in fields at Lumberton, Chadbourn, Braswell, Pembroke, and other places, including the fields around West Raleigh, where many bill bugs bred during the last two seasons. Without recording details of the work, it may be stated that the beetles have never been discovered during the winter months, that is, December to March, inclusive, except in one instance, at Chadbourn, when a single specimen was taken in the

edge of a rice field on March 29, 1911. On that date one beetle was found in a clump of grass, where it was moving about; hence it was not exactly in hibernation. Sticks, stones, logs, dead grass and weeds, brush, and, in fact, every movable thing in the field, have been overturned in the search for beetles in hibernating quarters other than cornstalks."

Just what becomes of the early maturing adults has never been determined. During mid-season the adults seem to emerge from the pupal cells in from five to seven days after transformation; later in the season this time seems to be gradually extended, and the late beetles remain in the pupal cells all winter. The writer believes that the early maturing beetles leave the cornfield late in the season, especially if the corn has been planted early, and migrate to later corn or to adjacent patches of cyperus grass, where they undoubtedly go into hibernation anywhere in the field a few inches below the surface. No beetles have been found save those that were still in pupal cells, in spite of the fact that we have sifted the top five or six inches of soil in many different parts of various cornfields that had been badly infested with bill bugs the previous season. Any one, however, who has had any experience with bill bugs in the field will appreciate the difficulties involved in attempting to locate bill bugs by sifting, and it is not at all remarkable that we were unable to locate them.

BEETLES FROM EMERGENCE TO HIBERNATION

Just where the early maturing adults spend their time from the time when they emerge from the pupal cells till they go into hibernation is still in part an unsolved problem. Part of the adults, evidently late maturing ones, remain in the pupal cells over winter; and part of the early maturing adults emerge from their pupal cells and feed in the same fields with their parents. Whether these young beetles lay any eggs the first season or not is discussed in another connection.

In fields of early or medium early planted corn the corn reached maturity in early September, and in such fields all the adult bill bugs have practically disappeared by late August. In later planted corn, especially in extremely late corn, the stalks may stay green and tender until after heavy frost, and the adults continue in such fields until late October, at least, evidently not seeking hibernation quarters until early November. In most cases, however, no such late corn is available, and it therefore becomes a problem to determine just where the adult bill bugs live from late August to early November. In the hope that we would be able to solve this problem, something in the neighborhood of five hundred pairs of adult corn bill bugs were marked in various ways in early August, 1912.

The adults marked in 1912 had a spot of bright water color painted either on the thorax or the elytra, as this method of marking had been

previously tried out very successfully in studying the diurnal activities. However, none of these beetles were ever seen after the last of August. Believing that the water-color paint used during 1912 might have been removed in the ordinary daily activities of the beetles, other pairs were marked by clipping their elytra during August, 1913 and 1914. None of these beetles were seen after mid-September and only a few after late August. Not many were ever seen far from the place where they had been marked, although a few were recovered in adjacent fields. None of the beetles marked in 1913 were recovered in 1914, and none of those marked in 1914 were seen in the spring of 1915.

However, in spite of this negative evidence, the writer is of the opinion that the beetles leave the early corn-fields in late August, either traveling to late fields of corn or to patches of cyperus grasses. This conclusion is strengthened by the fact that the bill bugs seem to disappear from the corn-fields very suddenly, and there is some very strong evidence from observations made in the insectary to show that late in the season the adults seem to develop a sudden instinct to fly. This is perhaps true in the field, also, and would naturally account for the sudden disappearance of the beetles from the corn-fields, as in the insectary all the beetles seem to acquire the instinct to fly at about the same time.

We have made no direct observations in the field that the beetles fly, save the indirect deductions as outlined above. If the beetles do acquire the instinct to fly from the fields, it would aid very materially in dispersing the species and would be a very important phase in their life cycle.

Careful counts of the numbers of beetles per acre have been made on small plats averaging one-third acre each. In these counts an effort was made to secure every beetle present in the field. Some were undoubtedly missed, but our counts usually showed an average of about 1,100 beetles per acre in mid-August, this number dropping so suddenly that by the last week in August there would be on the average from 75 to 100 beetles present per acre.

MORTALITY DURING HIBERNATION

The mortality during hibernation has varied greatly in our insectary experiments. It has ranged from about 10 per cent in some cages to over 90 per cent in other cages. Beetles for our hibernation experiments were placed in various kinds of cages. Some were placed in jelly glasses with varying amounts of sand and varying numbers of beetles in each glass. The mortality seemed to increase with the increased numbers of beetles in a single jelly glass. Some beetles have been held over winter in large screened cages, where they had on the average about six inches of soil in which to bury themselves. These cages were exposed out of doors, and the beetles usually went into the

soil to a depth of from four to five inches. In those cages that were left undisturbed the mortality was usually only about 10 per cent. A single disturbance of the beetles seemed to increase the mortality very much, and in cages where the beetles were disturbed several times they all died.

In the fields careful counts of plats averaging about one-third acre show that normally the numbers decrease from a rate of about 1,250 per acre in July of one season to about 420 per acre by the end of May the following season, by which time it is believed all of the adults have emerged from hibernation. This would give a mortality of about 66 per cent, provided all the beetles returned to the same fields; but, as pointed out in another connection, we have not been able to prove that any of the beetles returned to the same fields in which they worked the previous season, although, in spite of our negative evidence, some beetles undoubtedly do return to the same fields.

NATURAL ENEMIES

The corn bill bug is singularly devoid of natural enemies in all its stages. So far in these investigations no parasitic enemies of any of the stages of the bill bug have been discovered, and only a very few predaceous enemies. In the corn-fields in the eastern part of the State adults and larvæ or various species of ground beetles, lampyrid beetles, digger wasps, robber flies, and other predaceous insects, abound. Various species and individuals of these predaceous insects have been watched often for considerable periods. There is no indication that these insects prey upon any of the stages of the corn bill bug. Even when eggs, larvæ, and pupæ were exposed directly in the path of these predaceous insects they made no effort to devour them.

The little brown corn-field ant is also constantly present in the fields, and these have frequently been observed with eggs of the corn bill bug in their jaws, evidently having picked up eggs that were carelessly deposited or that had been deposited in the ground among the roots. There is no evidence that this ant enters the egg cavities and removes eggs that have been carefully deposited, although they are constantly running up and down the stems of corn plants, especially corn plants infested with root lice. In fact, the eggs are for the most part so well placed that it is rather doubtful whether ants would be able to secure any carefully placed eggs. However, ants have been seen with eggs so frequently in the field that one is led to suspect that they destroy a great many eggs in this way. Mr. Smith well says (Smith, 1913): "An egg dropped or placed on the ground or exposed on the plants is very quickly taken away by the little field ants. Just how much benefit they cause by destroying the eggs the writer has not had a chance to discover."

In October, 1915, I chanced upon the following observation, which is given in some detail because insect enemies of the corn bill bug are so

rare. In pulling up a stalk of corn in a field which had been planted in early July, I discovered a larval Tabanid firmly anchored to a larva of a corn bill bug of large size which was evidently nearly ready to pupate. It took considerable force to dislodge the Tabanid larva, which was placed in a tight tin box with four other good-sized corn bill bug larvæ and two pupæ. After a few minutes the box was examined and the Tabanid larva had again attached itself by its mouth-parts to one of the corn bill bug larva. The box was placed together with some other boxes and brought back to the laboratory, where opportunity was not offered for an examination until the following day. By this time the Tabanid larva had died, although it had completely eaten the four larvæ and one of the pupæ with the exception of the hard outer chiten and had eaten a hole into the side of the other pupa.

On the face of this observation it would look as if Tabanid larvæ might be very important enemies of Sphenophorus larvæ and pupæ, especially those that are exposed in the ground among the roots of the corn plant, for the predaceous habits of Tabanids are well known and they both occupy the same sort of situations generally, *i. e.*, moist, swampy situations, and must, therefore, be thrown constantly in contact. However, this single observation is the only evidence we have bearing on this point, and we have examined hundreds of larvæ and pupæ in the fields both in cyperus swamps where the natural conditions for the Tabanid larvæ would be good and in corn-fields where the natural conditions would not be so good. The same day the above observations were made we spent much time searching for other Tabanid larvæ, but none were found either in the field where corn bill bug larvæ abounded or along the ditch banks under very favorable conditions for Tabanid larvæ.

Mr. Smith was much troubled in his investigations by a small mite which invaded the insectary. Of these mites he makes the following statement (Smith, 1913):

"Mites have proved to be a pest of both the larvæ and the pupæ in confinement; but field observations do not show that the same thing is true under perfectly normal conditions. During the breeding work many larvæ are apparently killed, or worried so as to prevent regular growth, by a small mite identified by Mr. Banks as *Tyroglyphus americanus* Bks. These mites were often found on the bodies, or in their feeding channels, and usually such larvæ did not grow well. Very young larvæ were sometimes killed by the mites."

During 1913 the insectary was moved and we have had no further trouble with this mite. Neither has the mite ever been observed in the field in the natural burrows.

A good deal of trouble has been experienced in our breeding work with both larvæ and pupæ, which had apparently died from attack of some fungous growth. However, such larvæ were usually found in stalks of corn that were badly decayed or molded, and the chances are

that the larvæ had died from the want of proper food and the fungus had only attacked the larvæ or the pupæ secondarily. Concerning this point, Webster (1912) quotes Dr. Chittenden as follows:

"In another instance, during the last week of August, larvæ of this same species were dying and specimens were referred to Dr. Haven Metcalf, a Pathologist in the Bureau of Plant Industry, who stated that they were apparently free from fungi, and that while there was a possibility of the presence of a bacterial disease, such presence could not be established at that stage. Examination, however, revealed the fact that the bodies of the larvæ were fairly reeking with nematodes, and it is not impossible that these are the cause of the insect fatality."

In our observations no nematodes have been found either in the insectary or in the field. A condition similar to the above seems to be very prevalent among young larvæ, especially late in the season, and for this reason we have concluded that the death of the larvæ was due to poor food.

Toads also abound in corn-fields infested with corn bill bugs, but there are no direct observations to show that toads eat corn bill bugs in any stage. Neither has the examination of toads' stomachs revealed the presence of bill bugs. As a matter of fact, from direct observations one would almost conclude that the toad's eyesight was not good enough to distinguish the slow moving bill bug, whose natural color is so similar to the soil in which it lives. Attempts to feed bill bugs to toads have always resulted in the toad ignoring the bill bug.

Only one bird other than the domesticated fowls has been recorded as feeding on corn bill bugs. According to Webster (1912), "Mr. W. L. McAtee of the Biological Survey has recorded the findings of *Sphenophorus callosus* in the stomach of the nighthawk (*Chordeiles acutipennis texensis*) at Wallaceville, Texas, August 4, 1907. This is the only exact record obtainable of the eating of this species by birds."

Nighthawks are very common in the eastern part of this State, especially late in the season. But their well known habits of catching their prey on the wing has earned for them the distinctive name, "Bull Bat." This habit would seem to preclude these birds from being considered as important enemies of the bill bugs, unless, as pointed out in another connection, the bill bug has a fall dispersal flight, which would naturally come at about the same time as the greatest abundance of nighthawks, due to their southern migration.

Chickens and turkeys are believed by many farmers to be important enemies of bill bugs, and this may well be true, but we have made no direct observations on this point. One farmer in the eastern part of the State says that several years ago he had to yard his chickens to prevent them from running in a corn-field badly infested with corn bill bugs, for the bill bugs frequently lodged in the throat of the chickens or apparently attached themselves to the tongues with their sharp mandibles in such a way as to choke the chickens.

CONTROL

The control of the corn bill bug is not an especially easy farm practice. This is due to a number of different factors. In the first place, the insect cannot be attacked by any direct remedies, both because of its hardness and because most of its life is spent in the stalk of corn or buried beneath the ground. The only direct method that might be used to any avail against this insect is hand picking of the adults in the early spring and destroying them by throwing them into boiling water or kerosene. This practice would be too expensive to use on general crop corn, but might be used in small fields of corn which were being grown for roasting-ear purposes. If this method were to be used it would be advisable to scatter chips about the field under which the bugs would crawl during the middle of the day and from which they could be collected readily.

In the main the farmer in the bill bug section of the State will have to depend upon a slight modification of his usual farm practice to control the corn bill bug.

Careful observations made during the past several seasons show quite clearly that the control is not a very easy matter. It has also been clearly demonstrated that no one method can be used with any great success against this insect, but rather that the control is dependent upon a number of factors which, taken together, give us a system of corn farming somewhat different from the systems practiced in the corn bill bug section at the present time. These factors are discussed separately in some detail below, but it must be emphasized again that the farmer cannot put his dependence in any one method alone, but, instead, that he must work out a system of corn farming with these various factors in mind. In this connection it must also be emphasized here that a system which is built upon a basis of the factors here given is not necessarily a good system for growing corn in all sections of the State under all conditions, but rather that this is the system the farmer should employ in the corn bill bug sections of the State if he hopes to grow corn with the minimum of loss by corn bill bugs. Neither is it intended to imply that this system will avoid the attacks of other insect enemies of corn, but is simply to be used where the corn bill bug is the most important insect enemy of corn. The writer believes that the farmer who follows this system will also be doing the most important things in the control of many of the more important insect enemies of corn; but there are so many factors involved both in the many varieties of insect pests and climatic and other conditions which have not been studied in detail that it would not be surprising if certain insects were not controlled by following the suggestions as outlined here.

The writer believes that the following are the most important factors involved in any system for the control of the corn bill bug, both from the standpoint of ease and cheapness of application: (1) time of plant-

ing, (2) rotation of crops, (3) fertilization, (4) drainage, (5) ridging, (6) fall and winter plowing, (7) thorough cultivation, (8) destruction of native food plants. It will be noted at once that all of these factors are what might be called indirect methods of control. From the very nature of the case it would be impossible to apply any direct methods, for all such methods are expensive and the returns from corn are never great enough to justify the expense involved in their application.

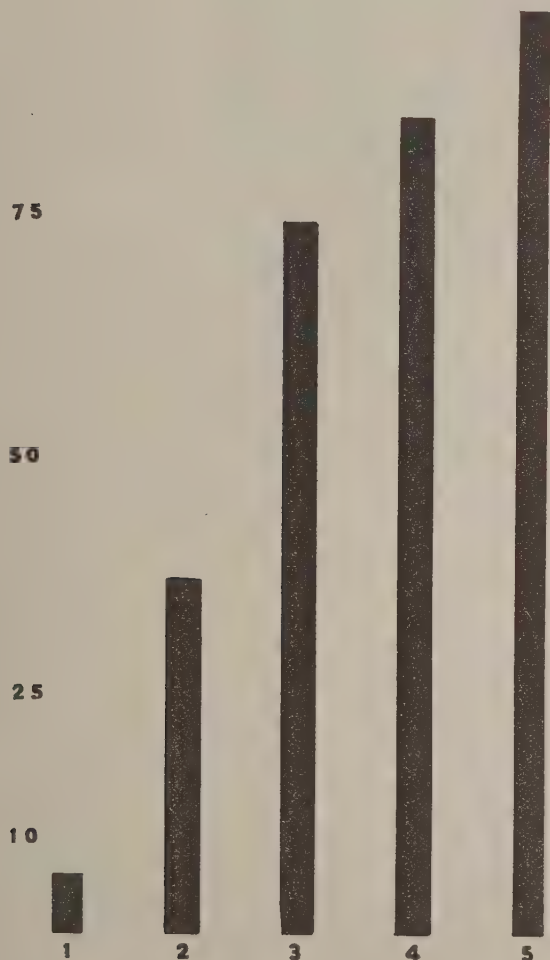


FIGURE 65. Diagram showing the percentage of corn injured when planted at different dates, in Renville County. 1. Corn planted late in March. 2. Corn planted mid April. 3. Corn planted early May. 4. Corn planted early June. 5. Corn planted early July.

TIME OF PLANTING

A series of experiments carried on during 1912 proved very conclusively that time of planting is an important factor in the control of the corn bill bug. Plats of corn were planted on the following dates: March 23, April 13, May 3, June 3, July 3. Careful inspections were made of these plats from time to time, and the following rough percentages will give an indication of the amount of injury:

<i>Date Corn was Planted.</i>	<i>Percentage Injured.</i>
March 23	6
April 13	37
May 3	74
June 3	85
July 3	94

From these figures it seems safe to conclude that in order to grow corn successfully in the corn bill bug section of the State it is necessary to plant the corn before the middle of April. However, too much dependence must not be placed in this one factor; for if all the other elements that go to make up the successful method of control of this insect are neglected, early planting alone will not insure a successful crop.

The reason that early planting is successful against this insect is undoubtedly because the early corn gets a start and is thus able to keep ahead of the attacks of the bugs. In the fields it always seems that when corn gets to be about waist high it is no longer much troubled by corn bill bugs, but that it is able to continue growing in spite of their attacks. Corn planted in late March in the eastern part of the State in the usual season has made such a satisfactory growth before the bill bugs come out of winter quarters that it continues to grow right along in spite of their attacks. On the other hand, corn planted after mid-April is just coming up at the time of the greatest prevalence and greatest activity of the adults. Fields planted at such times are so badly damaged that they cannot produce a satisfactory crop.

ROTATION OF CROPS

Rotation of crops is an important factor in the control of the corn bill bug, just as it is in the control of other important insect enemies of farm crops. This is due apparently to two reasons: (1) To the fact that if crops are moved from field to field the insects are forced to move also, because, as a general thing, insects which feed on corn do not feed upon other farm crops. In forcing the insects to move in this way, the chances are that they will not be able to find the new location, and as a result will die for the want of feed. (2) When corn is grown continuously on a field for a number of years the food which the corn requires

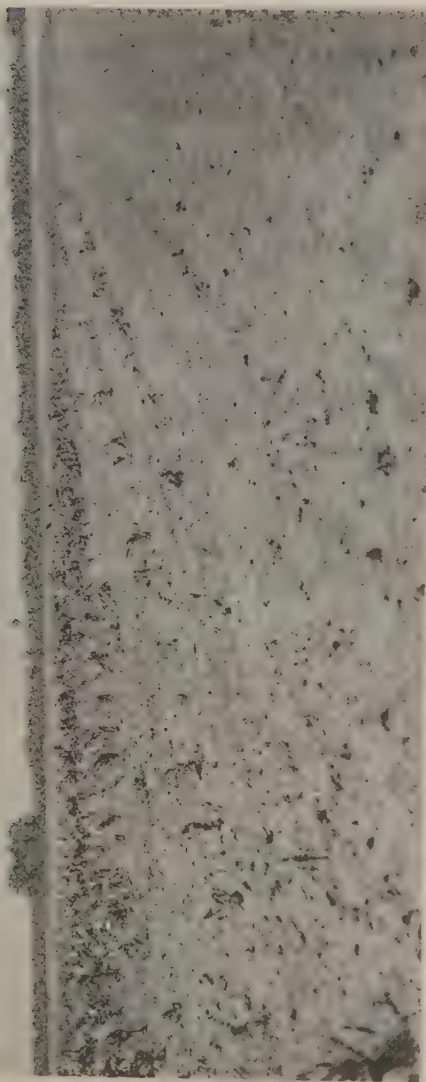


FIGURE 66. Experimental plots on Pender Test Farm showing the advantage of early planting. Corn on extreme left planted late March only very slightly injured. Mid April planting not much injured, but more injured than the late March planting. Next rows to the right planted early May very severely injured. The two rows on the extreme right planted mid May almost completely destroyed.

becomes so exhausted that the corn does not make a satisfactory growth, and hence it readily succumbs to the attacks of insects. Whereas, if proper crop rotation has been practiced, the corn would get a satisfactory start and would be strong and vigorous enough to withstand the attacks of insects to a certain extent at least.



FIGURE 67. Experimental plots showing the effects of heavy applications of complete fertilizers. Row in center and on either edge of plot heavily fertilized. Other rows without fertilization.

FERTILIZATION

Fertilization is, perhaps, next to "time of planting," the most important factor in the control of this insect. This is not, of course, the proper place to enter into a discussion of the proper fertilizer to use for corn, but it has been shown on one of our experimental plats that an application of fertilizer will make the plants grow much more rapidly, and hence be less liable to be fatally injured by the corn bill bug than plants which have not been heavily fertilized (Fig. 67). In the same way a heavy application of lime to land that is sour will make the plants grow much more rapidly and thus escape the attacks of the bill bug. The importance of lime may be further emphasized by the fact that very much of our corn land in the corn bill bug sections of the State is naturally very acid.

The belief so prevalent in the corn bill bug sections that fertilizers act as repellents against the corn bill bug does not seem to be based on facts. Repeated experiments with various mixtures of fertilizers, air-slaked lime, tobacco dust, tobacco extract, and basic slag failed to show that the adult beetle was deterred from feeding and laying eggs in

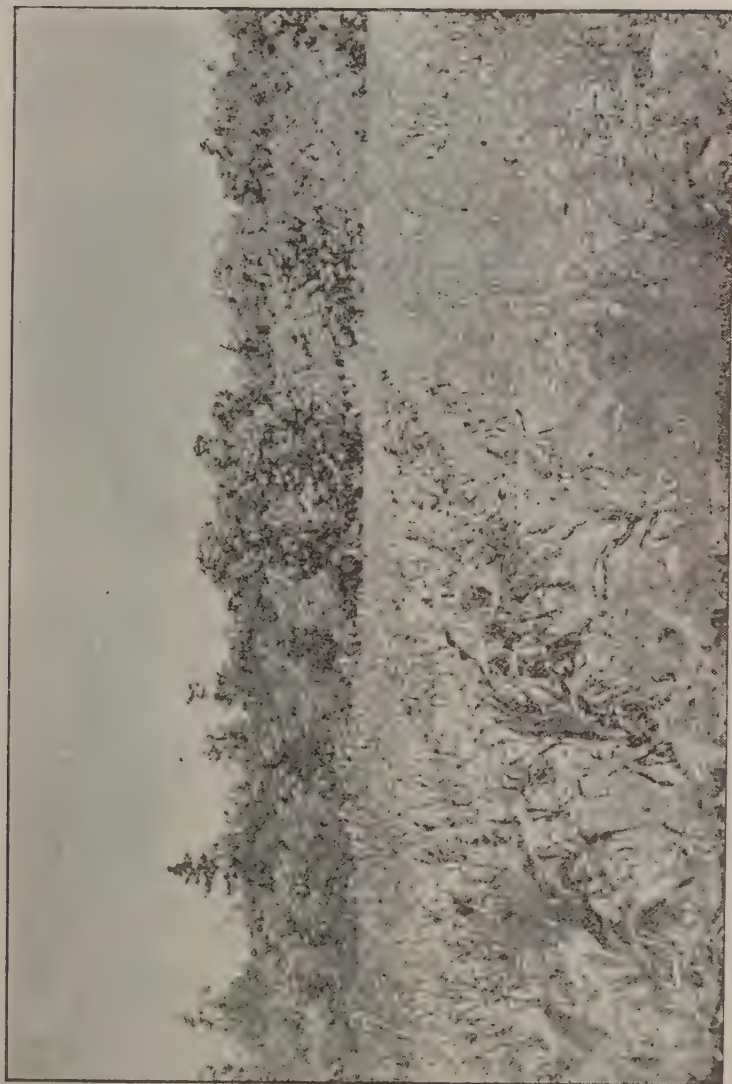


FIG. 11. 68. Experimental plots to show effect of ridging; row in center and either edge of plot ridged; other rows planted on the level.

plants thus protected. In some cases the material used as a repellent was actually mounded around the base of separate cornstalks, yet the beetles crawled over the mounds of the supposed repellent to feed upon the protected stalk. In all cases where a repellent action has been ascribed to any fertilizer, the writer is of the opinion that the results observed are not due to the repellent action of the fertilizer, but to the fact that such plants are growing rapidly, owing to an excess of food material; hence they escape the attacks of this insect.

DRAINAGE

It is a matter of common observation that the corn bill bug is worse in low wet lands than it is in uplands. Naturally this has led to the statement that the most important factor in the control of the corn bill bug is proper drainage of the land; and while this is an important remedy, its importance might easily be over-emphasized. The Pender Test Farm is exceptionally well tile drained, yet the bill bug has not become a negligible factor on this farm. And while we must not leave the impression that proper drainage is not an important factor in the control of this insect, yet we must caution the farmer against assuming that drainage is all important. It would not be possible for the corn bill bug to be worse than we have observed it on some well drained fields. (Fig. 2.)

RIDGING

Observations made in fields in various parts of the bill bug sections of this State show that stalks of corn which are on a slight elevation above their neighbors nearly always escape the attacks of the corn bill bugs for a longer period. Sometimes stalks which are on very slight elevations will not be attacked, while all the rest of the corn in the field has been very severely injured. The amount of immunity to attack seems to be out of all proportion to the height of the ridge. This was especially noticeable in a field on the Pender Test Farm, where many stumps had been recently pulled. In pulling the stumps a ridge of earth was left around a hole which was usually quite shallow after the plow had passed over it. Corn on this ridge either was immune from attack or was attacked only after all the other stalks in the vicinity had been seriously injured or killed. This led to the belief that if corn was planted on a ridge it would to a certain extent escape from the attacks of the insect.

This method was tried, and three rows through one of the plats (Fig. 68) were planted on a ridge which averaged about eight inches high. Corn was planted on these ridges and in rows between the ridges on June 20th. Careful examination made a month later showed that 45 per cent of the corn on the ridges had been injured, whereas 98 per cent of the corn in the rows between the ridges had been injured. An-

other examination showed that the corn on the ridges had been able to continue its growth and was much more advanced than the corn on the level.

This method is not generally applicable, owing to the cost of constructing ridges. It is mentioned in this connection because it might be used for the growing of early corn for market purposes where the expense involved would not be such an important item. This method must not be confused with the general practice of ridging corn at the time of the last cultivation. In the ridging method as here outlined the corn is planted upon a ridge. This method would be applicable only to lands that are very moist and where bill bugs normally abound, and not to lands that are very dry.

FALL AND WINTER PLOWING

Fall and winter plowings have been tried to a limited extent upon small plats, but no very striking difference could be noted in favor of this practice. However, if most of the adults live over the winter in the fields, the plowing of the land in the late fall or in the winter would disturb them very seriously and would act as a decided check upon their ravages. If, on the other hand, only a small number of beetles live over winter in the corn-fields, then the fall or winter plowing would not be such an important factor in the control of the bill bugs. The writer believes, however, that even if it should be proven that only a fraction of the adults hibernate in the corn-fields, the practice of fall or winter plowing would be profitable as a factor in the control of the corn bill bug where the same field was to be planted to corn two years in succession.

THOROUGH CULTIVATION

It has been stated that frequent shallow cultivation will keep the corn bill bug in control. And there are many things that would lead one to believe that this might be true. As discussed above, the adults spend considerable time hiding away under clods, etc. Therefore, it would seem but logical that cultivation would have a tendency to break up these retreats, and, if the cultivations were frequently made, that they would have a tendency to keep the insects disturbed; and these factors perhaps have some importance. However, a rather long series of observations has led the writer to believe that the effects of cultivation are not upon the bill bugs directly, but are rather upon the corn, causing it to grow more rapidly, and hence to be much more resistant to the attacks of all its pests. Observations show that corn that is well cultivated will generally make a better growth when attacked by corn bill bugs than corn which is improperly cultivated; but, on the other hand, the writer has frequently seen corn succumb to the attacks of this insect when, so far as he could determine, the corn had had the very best of cultural attention. Then, again, counts of the number of bill

bugs per acre made in widely varying localities and ranging from fields in a high state of cultivation through innumerable graduations to fields that had just been cleared and never plowed, but in which the corn had been "stuck," failed to show any constant correlation between the state of cultivation and the number of bill bugs present per acre. During 1915 the corn in the experimental plats on the Pender Test Farm was given very poor cultivation and was badly damaged by corn bill bugs, but the adjacent plats which were devoted to other experiments were given very careful cultivation. Yet, so far as could be determined, both plats were about equally injured. At least, the plats devoted to the other experiments had to be replanted, owing to the great amount of injury by corn bill bugs.

However, the writer does not mean to imply by any of the above statements that corn could be grown as well without cultivation as with proper cultivation. Nothing could be farther from the truth. Yet it does seem worth while to correct a growing misconception to the effect that proper cultivation is an early effective method of control for the corn bill bug.

DESTRUCTION OF NATIVE FOOD PLANTS

The corn bill bug is undoubtedly a native insect, and, like many other insect pests, fed formerly on various kinds of weeds. So far as has been determined, these weeds were mostly grass-like plants, especially the grasses which are closely related to nut grass and chufas. The corn bill bug still continues to feed and breed on these grasses throughout its range in this State. Therefore, corn grown in close proximity to such grasses or in fields where such grasses have been allowed to grow, is more apt to be injured by this insect than corn grown in fields that are free from these grasses.

Therefore, anything that can be done to keep down the native food plants of this insect will be important factors in its control. Many of these grasses are swamp-loving forms. Therefore, as the swampy areas on the farm are brought under better and better drainage these plants will be restricted in area and will therefore furnish less food for the corn bill bug. This will lessen the danger of the insect spreading from its native food plants to corn. In this connection, the farmers in the bill bug sections of the State should pay particular attention to drainage of swampy areas where the native food plants abound, and should also watch, closely, the edges of ditch banks and similar situations to see that such places do not grow up in these grasses which would furnish these pests with an abundance of food and would act as incubators for their increase.

Also, it seems hardly necessary to say that if some other crop would be grown on swamp land for the first year or two after it is cleared, it would have a tendency to reduce the damage done by this insect.

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